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Human Mobility and the Globalization of Knowledge Production: Causal Evidence from Multinational Enterprises*

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Abstract

We investigate how reforms that ease or restrict human mobility affect global innovation. We leverage a unique dataset merging patent data with exhaustive information on business-related migration reforms that take place in 15 countries over 26 years, and employ a novel event study approach. Our results show that reforms favoring inventor mobility increase the patenting, including global collaborations, of MNEs within a country, while the opposite is true for reforms discouraging inventor mobility. Further, we show that positive migration reforms partly explain the increasing share of global knowledge production by countries with low initial patenting observed over the past decades. This suggests that policies affecting human mobility contributed to the global shift in the geography of innovation towards emerging markets.

JEL Codes: J61, K37, O33, O34, O38
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1 Introduction

Multinational firms (MNEs) play a seminal role in global innovation. Recent estimates suggest that the top 50 MNEs alone filed 27 percent of all U.S. patents granted in 2019.[1] The past two decades have also witnessed MNEs conducting innovation more globally. In 2018, the U.S. Bureau of Economic Analysis (BEA) estimated that the 20-year growth rate of R&D activities of multinational companies in foreign countries, estimated to be 6 percent, exceeded the growth rate of R&D in the U.S., estimated at 4 percent.[2] Emerging markets such as China and India constituted a negligible share of global patent production in the beginning of the 1990s. However, by 2018 the World Intellectual Property Organization (WIPO) reported that China alone accounted for almost half of all the world's patent filings, with India also registering impressive increases in global patent production.[3] This leads to the question of what mechanisms contribute to MNEs increasing their innovation output globally as well as shifting innovative activities between countries, which is the focus of this paper.

Recent literature in economics acknowledges that the geography of innovation of MNEs is changing. Prior literature (see Hymer 1960; Caves 1971; Carr et al. 2001) argued that knowledge generating activities such as patenting should be conducted within the high-skill labor-intensive headquarters of the MNE, and that inventions patented at home could then generate profits in foreign markets through production abroad. However, recent evidence, notably Branstetter et al. (2006), Foley and Kerr (2013), Branstetter et al. (2014), Miguelez (2016), and Kerr and Kerr (2018), documents a changing view of innovation within MNEs where international co-invention and global collaborative patenting becomes increasingly central.[4] This view suggests that technological development may depend on localization, as MNE innovation is increasingly recognized

[1]https://techcrunch.com/2020/01/14/us-patents-hit-record-333530-granted-in-2019-ibm-samsung-not-the-faangs-lead-the-pack/

[2]https://www.bea.gov/sites/default/files/2020-08/omne0820$_0$.*pdf*

[3]Source: https://www.wipo.int/pressroom/en/articles/2019/article$_0$012.*html*

[4]MNE innovation is increasingly linked to international localization. Branstetter et al. (2014) document that MNEs from advanced industrial economies are largely responsible for the "exponential" growth in U.S. patents filed from China and India, such that "MNE sponsorship accounts for the majority of new US patents granted to Indian or Chinese inventors in recent years" (pp. 139-140, ibid.). Further, Kerr and Kerr (2018) cite analysis from the Bureau of Economic Analysis to state that the share of R&D for U.S. MNEs conducted by foreign subsidiaries rose from 6% in 1982 to 14% in 2004.

to rely on the knowledge production and absorptive capacity of its subsidiaries. In this theory, the subsidiary acts as a source of knowledge which relies on locally hired workers, (Cohen and Levinthal, 1990; Minbaeva et al., 2003; Minbaeva, 2007; Chang et al., 2012), and/or as a source of knowledge flows which rely on transferred human capital (Kerr et al., 2016). Cross-border mobility of inventors is highlighted as a key mechanism for global knowledge production by MNEs, but evidence of this relationship remains thin, especially in a multi-country setting, which is essential to understand geographic shifts in the production of global innovation.[5]

The purpose of this study is to explore this interrelationship. Specifically, we do so through investigating whether and to what extent MNEs' subsidiary-level output in innovation changes following immigration reforms that ease or harden barriers for business travel into a country. To do this, we put together a new dataset with the exhaustive list of business-related migration reforms adopted in 15 countries over the period from 1990 to 2016 (59 in total), which we match with the patenting activities of 11'479 MNEs and their 32'553 country-level subsidiaries.[6] Subsidiary information is taken from the universe of all USPTO patents, which allows linking subsidiaries with disambiguated MNEs, and to follow inventors over time and thus to identify movers across countries, or global migrant inventors (GMIs), following the term used by Bahar et al. (2021).[7] In our analyses, we consider patent outcomes of three types: (1) overall patent counts, (2) global collaborative patents, or GCPs (defined as those patents with a geographic footprint that crosses international borders), and (3) domestic patents (patents where all inventors reside in the same country at the time of filing). We also use fine-grained data on inventors' mobility to measure how the changes in migration policy affect cross-border human capital flows and consequent patenting

[5]Starting with Edström and Galbraith (1977), scholars have documented that geographic mobility of human capital enables multinational firms to transfer and exploit knowledge more efficiently in the intra-firm context than would be possible through external market mechanisms (Almeida and Kogut, 1999; Rosenkopf and Almeida, 2003; Oettl and Agrawal, 2008; Foley and Kerr, 2013; Singh, 2005; Choudhury, 2016). In addition, extensive literature examines cross-border ethnicities as a key mechanism in facilitating global knowledge co-production as documented by Branstetter et al. (2014), Foley and Kerr (2013), Kerr (2008), Kerr and Kerr 2018, Saxenian (2002); Saxenian et al. (2002); Saxenian (2007). However, relatively few studies examine how migration policy influences the geography of patenting within MNEs, especially *across* countries.

[6]The countries included in our data are Brazil, Canada, Chile, China, Germany, India, Italy, Japan, Mexico, the Philippines, Portugal, South Korea, Spain, Taiwan, and the United Kingdom.

[7]In our data, subsidiaries are identified as the interaction between MNEs and countries where patents are filed. Following (Bahar et al., 2021), an inventor is considered a GMI if he or she is observed patenting in a different country with respect to the one of first appearance in the data.

of GMIs themselves, as well as patenting of never-movers in an effort to explore spill-over effects.

A key challenge for causal inference is that the behavior of MNE subsidiaries is not necessarily exogenous to the country-level enactment of migration policy changes, especially without accounting for size. In fact, while unlikely, MNEs may anticipate such events and redeploy resources dedicated to innovation accordingly. In an effort to reduce endogeneity concerns, and in order to establish causal estimates of how MNE subsidiaries are affected by such changes, we employ an exposure-based event study design that identifies plausibly exogenous variations in the level of exposure of different subsidiaries to these reforms, prior to the reform itself. In particular, we leverage the fact that subsidiaries belonging to MNEs with a strong culture of international human capital rotation, which we measure through the historical rate of inventor mobility observed within the MNE in all other countries of operation, might be more responsive ex-post to policies affecting business travel.

Our results show that pro-business migration reforms significantly increase the number of patents filed by the MNE within a country, while the opposite is true for policies deterring business travel. Subsidiaries with one standard deviation higher exposure see an increase of 3.1% in patenting following a positive business reform and a 13.8% reduction in patenting following a negative business reform. The positive effect is mostly driven by additional domestic patents, while negative migration reforms decrease both domestic patents and GCPs and the magnitude of the effect is larger compared to positive reforms. Negative reforms also decrease the quality of the patents filed across three criteria: average patent originality, average radicalness, and number of citations per patent. Further, we show that negative migration reforms significantly decrease the share of global patents filed by subsidiaries in the country that implemented such policies, and that this effect is stronger for the historical leaders in global knowledge production: Japan, the United Kingdom and Germany. On the contrary, positive migration reforms substantially increase the share of global patents filed in countries with low initial shares of knowledge production. This finding suggests that policies affecting human mobility have contributed to the observed shift in the geography of innovation towards emerging markets.

In terms of mechanisms, our results seems to be explained primarily by changes in the number of patenting inventors, rather than by the number of patents filed by each inventor. Finally, our back-of-the-envelope calculations reveal that without positive migration reforms, the countries in our sample would have produced 45% less patents by the end of the period, while without negative reforms they would have produced 17% more patents than we actually observe. They also reveal that in the absence of migration reforms, the share of global innovation produced by emerging markets would have grown from 5% to only 20% between 1990 and 2015, instead of reaching 50% as we observe in the data. These results provide strong evidence that inventor mobility causally facilitates MNEs' global production of inventions and shifts the geography of patenting production, carrying important policy implications. In particular, the severe asymmetry in the effects associated with positive and negative reforms underlines how policies deterring human capital mobility are heavily detrimental to local and global knowledge production, and might be hard to reverse through subsequent improvements.

These results contribute to three strands of the literature. We first show that GMIs are a key input to the production of innovations among the modern MNE, and that MNEs react to policy changes affecting mobility costs by relocating their invention activities. Here, we contribute to the nascent literature on international co-invention and the global collaborative patenting activities of MNEs (Kerr and Kerr, 2018; Branstetter et al., 2014), and we are the first to show that even the production of domestic patents is causally dependent on the migration policy context. Second, the results emphasize the role of MNE subsidiaries in the knowledge generating process, and thus they underline the importance of their "absorptive capacity". This provides support for the knowledge-based view of the MNE, namely, that subsidiaries exist due to their ability to manage knowledge transfers in the face of international barriers to market transactions (e.g., Kogut and Zander 1996; Caves 1971; Cohen and Levinthal 1990).[8] Finally, we contribute to the literature on the role of migration policy for innovation outcomes of firms and regions by shedding light on the implications of business-travel-related migration reforms on local innovation by MNEs. This work adds nuance to prior research by outlining the implications of immigration policy changes

[8] This more broadly relates to the literature on the cost of knowledge transfers across borders (Giroud, 2013; Gumpert, 2018; Bahar, 2020).

for subsequent innovation via the mechanism of knowledge transfer and knowledge recombination (e.g. Kerr and Lincoln 2010; Borjas and Doran 2012; Doran et al. 2014; Hornung 2014; Peri et al. 2015; Beerli et al. 2018; Choudhury and Kim 2019; Bahar et al. 2020; Burchardi et al. 2020, Sequeira et al. 2020).[9] Our finding showing that changes in the number of global inventors in the subsidiary are associated with changes of roughly equal magnitude in the number of patenting domestic inventors echoes previous findings of complementarity in production between migrants and natives (e.g. Kerr et al. 2015; Choudhury 2016; Signorelli 2020).

In addition, we highlight a data and a methodology contribution. For data, we collected and introduce with this study a novel database indexing 253 migration policy changes in 15 countries spanning the years 1893-2016, with an emphasis on the period from 1990 forward, as described in Appendix D. With regard to methods, we outline an empirical approach for dealing with the econometric difficulties imposed by high-frequency events which are proximately clustered over time and for estimating causal effects given such setting.[10]

The remainder of the paper is organized as follows. Section 2 covers the data constructed for estimation, Section 3 outlines the empirical strategy, Section 4 presents the results, Section 5 describes the extensions to the main analysis, and Section 6 concludes. The paper is accompanied by an online appendix with supplementary materials.

[9] In the broader field, other research presents evidence on migration patterns and their shifts over time (e.g., Kerr et al. 2016; Czaika and Parsons 2017) as well as the empirical implications of immigration for local labor market outcomes (e.g. Borjas 2004, 2009; Hunt and Gauthier-Loiselle 2010). Even within the larger field, this study is one of the first to estimate effects across multiple countries and multiple events, as opposed to engaging in 'case study' analyses.

[10] The context we study suffers from an embarrassment of riches of sorts – the frequency of reforms events is so high for some countries that several events of the same general type occur across several consecutive periods within some countries. This clustered nature of reforms limits estimation under classical event study methods, where current practice is to consider only events which are to some-extent isolated over time from other events. If the current study were to follow this practice and drop observations with consecutive reform events, we would quickly suffer from a loss of statistical power, as our reforms are measured across only 15 countries. Instead, we take steps to adjust event-study methods to deal with the closely time-clustered nature of the reforms and go to lengths to demonstrate the relative robustness of the estimation approaches we employ in Appendix E.

2 Data

2.1 Migration Reforms Dataset

One of our main source of data in our study is information we compiled on dozens of migration reforms in over 15 countries over 26 years.[11] Our focus is on 59 migration reforms enacted during the years 1990 - 2016 that either increase the expected flows of immigrants to those countries from the rest of the world. The list of countries we selected countries are based on the presence of (i) historical enactment of intellectual property legislation supportive of patenting, (ii) multinational activity, and (iii) significant migration flows.[12]

Following collection, the primary documents and sources describing the reforms were analyzed to derive their anticipated effects on the volume and rights of different migrant types. For the sample considered, we isolated the reforms that specifically impact business-related migration. The reforms –which we detail fully in Appendix D– largely consist of changes in the visa application processes that either facilitate or harden the access to a country (e.g. standardization of entry procedures, introduction of 'point-based' systems selecting migrants with technical skillsets), or in changes in the benefits received by foreign workers after entering the country (e.g. allowing for access to health benefits and facilities).

Some examples of reforms include:

- In 2009, South Korea implemented substantial restructuring of the ways in which business migrants would access the country through the introduction of Contact Korea. The latter is a program establishing a public office in charge of centralizing and supporting firm

[11]These reforms were identified as part of a larger project to construct a systematic index of all unilateral policy reforms and governmental programs instituted across 15 countries and over more than a century, that were anticipated to drive changes in the migration patterns of high-skilled immigrants. More details on this project are described in Appendix D.

[12]Ten of these countries coincide with the sample analyzed in Branstetter et al. (2006), who study the impact of systematic reforms designed to strengthen and standardize intellectual property on MNEs foreign direct investments between 1982 and 1999. We began first with those countries sampled in Branstetter et al. (2006) and expanded the sample to 5 additional countries with the aim of including countries that are the source and destination of significant migration flows.

recruitment of global talents. The functions of the office include identifying business and recruitment needs as well as providing visa recommendation, immigration support, and relocation assistance. A year later, the government implemented HuNet Korea, a three-way platform that standardized business-related migration processes and digitally matched three groups: high-skilled foreign workers searching for employment, companies seeking employees with technical skill sets, and the governmental system necessary for approving visa applications. Together, these reforms established a cohesive platform for long-term business-related migration into South Korea. These reforms are thus coded as promoting both the volume of business-related migration (e.g. through incentivizing migration directly) and the rights of such migrants (e.g. through facilitating paths to residency).

- In 2009, the Department of Justice of the Philippines issued a memorandum requiring foreigners that have been granted a visa of more than 6 months to apply for an Emigration Clearance Certificate if they want to leave the country. The latter insures that the applicant has no derogatory records in the country and has no pending obligations with the government. In the same year, the Department of Labor made changes in the assignment of employment permits to migrants, aiming to prevent foreigners from "taking jobs that could be filled up by Filipinos". Following this reform, government officials might inspect establishments employing migrants to verify the legitimacy of their employment, while foreigners whose employment permit application is denied are not allowed to submit a new application. These reforms are thus coded as decreasing both the volume and the rights of economic migrants.

Table 1 summarizes the countries and timing of all the reforms included in the sample, with further classification into positive and negative ones.[13] It also reports the sub-sample of them that affects permanent migration, which identifies reforms affecting stays of 1 year or longer. The number of positive changes out-weights by more than 3 times the negative ones, which is in line with the general observation that international migration flows have been growing over the past 20

[13]Two policies include both positive and negative elements, and are thus double-counted in this table. They concern the United Kingdom in 2006 and Italy in 1998. For more details on this see Appendix D.

years. Some countries in our sample, such as Korea and Japan, for instance, experience numerous reforms that are temporally close to each other, which raises some challenges for the econometric strategy. In the next section, we propose a novel solution to cope with the high frequency of these events.

2.2 MNE Global Patenting Activity

Patents data comes from PatentsView, a data visualization tool maintained by the Office of the Chief Economist at the USPTO.[14] Among its many offerings, the open data platform contains the universe of patents *granted* by the USPTO from 1976 to present (naturally, many patents in the dataset have application dates prior to 1976) with some important characteristics that makes such dataset stands out. In particular, PatentsView uses complex algorithms to disambiguate the names of inventors and of assignees across time, resulting in a unique identifier for both inventors and assignees. The data on patents also includes the location of inventors at the time of filing of the patent, which along the unique identifier, allows us to track the inventors also across space (see (Monath et al., 2020) for more information on the disambiguation methods).[15]

Using the location of the inventors, alongside the unique identifiers for the assignee (typically an MNE) of the patent, we index the international 'geographic footprint' of each MNE subsidiary's innovation activity by measuring aggregate patent counts at the assignee-country level. We then limit our sample to MNEs and their subsidiaries using two criteria. First, we require that the assignees have produced patents in more than one country at any point over the period. Second, we restrict the sample to the MNEs with patent production in at least two of the 15 countries for which we have gathered reform information over the sample period (this is since MNEs patenting in only one of them would anyway be dropped by the fixed effects included in the analysis).

With these data we create a number of outcome measures defined below.

[14]The tool is a joint effort by the USPTO, American Institutes for Research (AIR), University of Massachusetts Amherst, New York University, University of California, Berkeley, Twin Arch Technologies, and Periscopic.

[15]Extensive prior work describes both the USPTO data and assignee disambiguation efforts (see Hall et al. 2001; Jaffe 2017; Balsmeier et al. 2018) as well as the role of patent data as an indicator of innovation (Trajtenberg, 1990; Hall et al., 2001).

2.2.1 Outcome Measures

Our primary outcome measures are counts of patents assigned to an MNE subsidiary in a given year. We consider the combination of an assignee and a country-of-inventor as an MNE subsidiary. In terms of time, since our goal is to exploit the point of time when the innovation happens, consistently with the standards in this literature, we define the date of a patent as the earliest between the application and the priority dates.[16] As our focus is on how global patenting activity shifts following such reforms, we focus on subsidiary-year production of patent classified as follows:

- **Total Patent Counts:** The sum of granted USPTO patent applications to a given assignee, applied for in year t by inventors in a given country of residence.
- **Global Collaborative Patent (GCP) counts:** A subset of the above, which include only patents to a given assignee applied for in year t, where at least one inventor lives in a country other than the subsidiary under consideration.[17]
- **Domestic Patent Counts:** A subset of the first one, counting only patents belonging to a given assignee where *all* inventors reside in the same country as the subsidiary.

Since we are interested in incorporating measures that reflect inventor mobility –as responding to migration reforms– as part of patenting activity, we use these data also to count patents by inventors who have moved across borders following migration reforms. Consistently with the work of (Bahar et al., 2021) we refer to inventors crossing borders as Global Mobile Inventors (GMIs). An inventor is considered a GMI starting from the point where he or she is observed patenting in a country different from the one of its first appearance.[18] With this definition, we create a number

[16]For patents that only have been filed in the USPTO, the application and priority date should be the same. For patents that have been filed in another patent office (such as the European Patent Office or the Japanese Patent Office, for instance), the priority date (often recorded in the patent record) refers to the date in which the patent was filed for the first time in any patent office.

[17]The concept of GCP is first described in Kerr and Kerr (2018), and we draw on that paper as our motivation for using GCPs to measure globalized innovation processes. While defined in that study as an MNE patent with a U.S. and an international invention team, we define a GCP as any patent with a geographic footprint crossing an international border.

[18]We tested the robustness of our findings using different measures of GMIs (e.g., such as an inventor being considered a GMI only during the first year after his or her cross-border moved is observed, and we find our results to hold. These results are available upon request.

of count variables to complement the ones above that will serve us in our empirical strategy:

- **GMI patent counts:** The sum of granted USPTO patent applications applied for in year t by the MNE subsidiary in a given country, filed by a team in which at least one inventor is identified as a GMI.
- **Non-GMI patent counts:** As above, but for all patents filed by a team in which *none* of the inventors is identified as a GMI.

Finally, we use different indicators constructed by the OECD to capture a measure of quality of the patents (Squicciarini et al., 2013). We end up with five distinct proxies for quality which we aggregate for each MNE subsidiary per year: i) patent generality, ii) patent originality, iii) patent radicalness, iv) share of patents considered breakthrough, and iv) number of citations per patent. We use these measures to present results for the impact of migration reforms on all these five innovation quality measures.

2.2.2 Reform Exposure Measures

We additionally use patenting activity to estimate the exposure of the MNE subsidiaries to the enacted reforms, as part of our identification strategy, which we use as part of our set of regressors. Conceptually, reforms impact MNEs by easing or complicating their effort to transfer human capital across countries. We posit that subsidiaries that are part of an MNE where the labor force is very mobile are likely to respond more to changes in migration incentives. For instance, following a reform restricting the rights of foreign workers, subsidiaries of very mobile MNEs might be more capable or willing to redeploy their employees elsewhere. The opposite can be imagined when a reform introduces new advantages for migrants.

Our measure of exposure is computed as the ratio between the number of mobile inventors that patented in all the other subsidiaries of the MNE, except for the one where the reform takes place, scaled by the total number of inventors.[19] This ratio is computed over a moving window of five years prior to each observation.[20] Given that our measure of exposure might still be somewhat correlated with the timing of reforms, even if it is computed using the mobility rate observed in other countries, we test the robustness of our results to an exposure measure that applies the same formula but uses the moving window spanning between 5 and 10 years prior to each observation. Results using this specification are reported in Appendix B.1.

2.2.3 Final sample

When the reforms are combined with the patent measures, the data consists of a finalized panel at the MNE-country-year level that is balanced within country and which consists of 127'543 observations indexing 11'479 MNEs with a total 32'553 subsidiaries across the 26 years observed. Descriptive statistics are presented in Table 2. A couple observations are of note. First, GCPs and patenting by GMIs represent the minority of patenting. Domestic patents represent, on average, approximately 86% of patent production by MNE subsidiaries in the reform countries in our sample. Similarly, the statistics suggest that GMI patents represent about 25% of an MNE patenting activity. GMIs are more prevalent in the production of GCPs, since more than 50% of these international collaborations are filed by a team counting at least one GMI. In a given year, the average subsidiary in the sample produces 14 patents. The distribution is however highly skewed: the median subsidiary only files 2 patents per year, while the one at the 95th percentile files 40 patents and the maximum reaches more than 6 thousands. On average, each subsidiary counts with 1.7 mobile inventors, which amounts to 17% of their total number of inventors. High exposure subsidiaries have 4 times more GMIs, which account for the double of the share of total inventors. Finally, MNEs with higher inventor mobility rate - our measure of exposure - are also the firms that patent the most. This is consistent with the fact that large corporations can invest more in the mobility of their employees, through the creation of dedicated HR teams dealing

[19] For this measure we only consider inventor mobility happening within the MNE and across countries, in order to capture the HR policy of the firm.

[20] We assign an exposure of zero to subsidiaries belonging to MNEs that only file patents by teams of never-movers in all the other countries over the window of interest. We also assign an exposure of zero to MNEs that are not observed patenting at all over the window of interest.

with the travel formalities, for instance. Interestingly, the quality of patents filed according to a number of measures is similar for both low- and high-exposure subsidiaries.

Appendix Table B1 displays the frequency of subsidiaries and patents of the different types across the reform countries during the years of the sample. There is substantial heterogeneity among the presence of MNE subsidiaries across the countries, with Western countries (e.g. Canada, Germany, the United Kingdom, etc.) showing the largest frequency of MNE implantation, followed by Asian countries (e.g. Japan, China, Taiwan). Additionally, certain countries produce global collaborative patents at greater rates than domestic patents and at significantly higher rates than those found in Kerr and Kerr (2018), underlining a wide heterogeneity in the knowledge production strategies.[21]

Finally, patenting rates rise significantly post-1980 (an increase that is well-documented in Kortum and Lerner 1999), and domestic patents rise substantially more than GCPs, as shown in Figure 1a. At the end of the period, there is a slight decline due to rightward censoring, explained by the time lag existing between patent filing and approval. In fact, to avoid our results being affected by this censoring, we limit our sample period to year 2016, though this has no qualitative impact on our findings. Beyond the observed growth in the number of patents registered in the USPTO data, we also observe significant growth in the share of inventors that move internationally, going from about 1% in the 1970s to 8% in 2015 (Figure 1b), consistently with what documented by (Bahar et al., 2021). We further observe a substantial shift in the distribution of patents across countries over the period (Figures 1c and 1d). In 1995 Japan filed 50% of all patents in our sample, followed by Germany (18%) and the United Kingdom (8%). Emerging markets such as China, India and Taiwan accounted for a negligible share of global patents. In 2015, Japan remains the leader of innovation activities, but its share of global patents decreased drastically, while China, Korea, Taiwan and India are starting to play an important role in global knowledge production. Over this period, there was a drastic shift in the geography of innovation production away from rich countries towards emerging markets. Our analysis below explores whether policies affecting

[21]They measure collaborative patenting rates among U.S. MNEs and find a rate approximately between 30% and 55%.

human mobility had a role in explaining such shift.

3 Empirical Strategy

Our empirical strategy applies an event study framework in which the identification relies on the assumption that migration policy reforms – our "treatment" events – are exogenous to the MNE subsidiaries within the enacting country. To ensure exogeneity, we exploit the fact that, although assignment of reform events is potentially endogenous to country-level characteristics and trends, subsidiaries within the same country vary in the extent to which they are capable of reacting to a given policy change. Thus, our identification strategy does not rely only on comparing countries with and without reforms before and after (given that governments may enact reforms in anticipation of shifting innovation trends inducing reverse causality) but rather compares MNE subsidiaries *within* the same country with different ex-ante exposure to these reforms. In particular, subsidiaries belonging to MNEs with high levels of initial inventor mobility rates are expected to be more responsive to legal changes affecting migration incentives ex-post. We model this as:

$$Y_{fct} = \beta_0 + \beta_1 exp_{fct} + \beta_2 exp_{fct} \times PRef_{ct} + \beta_3 Exp_{fct} \times NRef_{ct} + \gamma_{ct} + \delta_{ft} + \epsilon_{fct} \tag{1}$$

where Y_{fct} represents the innovation outputs in year t of an MNE subsidiary, defined as the combination of MNE firm f and country c. Given that the distribution of the number of patents filed by a subsidiary in a given year is very skewed, we run the regressions on arcisnh transformed outcomes, such that the coefficients can be interpreted in terms of growth rates, and the variables are also defined at zero (Card et al., 2020). The outputs are a function of exp_{fct}, the mobility rate of the MNE observed across the other subsidiaries, and the interaction of the latter with positive ($PRef_{ct}$) and negative ($NRef_{ct}$) reform events taking place in the country.

Formally, the exposure measure is defined by the following formula:

$$Exp_{fct} = \frac{\sum\limits_{c',t'} MobInv_{fc't'}}{\sum\limits_{c',t'} Inv_{fc't'}}$$

where $c' \in C|\{c\}$ and where $t' \in (t-5, ..., t-1)$.

To ease the interpretation of the results, the exposure measure exp_{fct} is standardized to have mean zero and a standard deviation of one. Given that in many countries we observe more than one reform over the period, both $PRef_{ct}$ and $NRef_{ct}$ are count variables indexing the cumulative number of reforms enacted by year t in the subsidiary country c (more on this approach below). The key parameters of interest are thus β_2 and β_3. The outputs are additionally conditioned on fixed effects at the levels of MNE-year (δ_{ft}) and country-year (γ_{ct}), in order to identify the effects of reforms independent of MNE and country trends. We estimate the model using OLS, and we cluster the standard errors at the subsidiary level.

The counterfactual modeled by this approach compares the change in innovation output of high exposure subsidiaries observed after the reform events with the same change observed among low exposure subsidiaries, while netting out changes attributable to the country and the firm over time. For our identification strategy to produce unbiased estimates, we must make two assumptions. First, that subsidiaries with initial low exposure serve as a control group for treated (high exposure) subsidiaries in the context of migratory reform. Second, that subsidiaries with similar levels of exposure located in places without reforms in a given period serve as control for those located in a country that experiences a reform in that period. In particular, our identification strategy relies on the fact that both the timing of the reform and the ex-ante exposure of the subsidiary, combined, are exogenous to the future patenting activity of the subsidiary. We believe that these are reasonable assumptions in our context.

As alluded to earlier, an estimation challenge in this setting is the presence of repeated reforms which are highly clustered in time. Standard econometric practice suggests isolating those observations only 'treated' once, or to estimate treatment effects only in short-run windows that do not include any repeated treatment events. However, neither technique is well-suited to the current setting. As reform events are enacted repeatedly within the large majority of our countries (the only exceptions being Brazil, Canada, Chile and India), omitting repeatedly treated observations would excessively reduce the sample. Reforms events are additionally clustered in time, which severely limits the sample of periods for which it is possible to estimate short-run treatment effects independent of other reform events (see Table 1).

To resolve this difficulty, we introduce a novel empirical approach to estimating treatment effects given repeated and clustered-over-time events. We do so through regressions that estimate the marginal treatment effect of each additional reform event. Specifically, we allow the event indicator terms ($PRef_{ct}$ and $NRef_{ct}$) to dynamically vary over time, changing in level as treatment events accumulate.[22] In our linear regressions, the key coefficients β_2 and β_3 are interpreted as the marginal effect of one additional reform on innovation outputs. Appendix E reports simulations that validate the estimator, discusses the additional assumptions it imposes on causal inference, and outlines a generalized version of the estimator that allows treatment effect to vary conditional on the level of consecutive events. We find that using our dependent variable as a count of reforms is a good approximation to the average effect of each reform separately.

4 Results

4.1 Stage "zero" results: Reforms and GMIs

Before moving to the main results, we test empirically for the basic premise behind our research question: namely, whether there is a change in the number of mobile inventors following a reform, and whether our exposure measure is indeed correlated with such changes. Table B2 in the Appendix tests the correlation between the cumulative count of reforms and the arcsinh-transformed number of GMIs in the subsidiary. Column (1) reports the unconditional coefficients,

[22] This term is akin to employing an 'intensity of treatment' variable in difference-in-differences, in which treatment obtains multiple levels or reflects an observation's propensity to treatment (similar to specifications employed in, e.g., Duflo 2001; Acemoglu et al. 2004), but where the intensity of treatment varies with time.

while columns (2) and (3) add controls for year fixed effects, and year and country fixed effects respectively. Finally, column (4) and (5) test the first stage obtained from the main specification displayed in Equation 1, using both contemporary and historical exposure.

Results show that one additional positive reform increases the number of GMIs by about 5.3%, while one additional negative reform decreases it by about 2.8%. With the addition of fixed effects, the coefficient becomes smaller for positive reforms, while it becomes larger for negative reforms. Finally, using our main specification, we find that subsidiaries that are one standard deviation more exposed, have on average 35% more GMIs than the mean subsidiary. One additional positive reform increments that value by 3%, while one additional negative reform decreases it by almost 8%. Taken together, these results confirm that migration reforms do affect the international mobility of inventors. In the next section, we analyze how this affects the location of knowledge production.

4.2 Main Results

In this section, we present the results obtained from applying the model described in Equation 1 on the main outcomes of interest. Table 3 reports the results for the total number of patents filed within a given subsidiary and for the break-down count between global collaborative patents and domestic patents.

Results show that more exposed subsidiaries patent much more on average, since one standard deviation higher inventor mobility rate is associated with 66% more patents overall, 19% more GCPs and 80% more domestic patents. More interestingly, we see that additional positive reforms significantly increase by 3.1% the total number of patents filed by exposed subsidiaries, which is entirely explained by the growth in domestic patenting activities. On the contrary, negative reforms decrease overall patents by 14%, which can be subdivided into a 3.5% decline in GCPs and a 14% decline in domestic patents.

These results underline how the location of the knowledge production by MNEs is highly dependent on the opportunities for mobility offered by countries, such that policies unilaterally adopted by different countries can long-lastingly change the geography of patenting activities. There are two interesting heterogeneities to be noted. First, domestic patents seem to be more dependent on inventor mobility than GCPs. Second, negative reforms seem to harm more the innovation produced in the country than positive reforms benefit it. For the latter, a caveat is that negative and positive reforms are not directly comparable with each other - negative ones might involve larger changes for instance -, and we have shown in the descriptive statistics that in our sample there are many more positive changes than negative ones. Nonetheless, these results do suggest that restricting immigration can have very detrimental effects on the innovation capacity of a country, which might be difficult to reverse with subsequent migration incentives.

It is worth considering now the extent to which our identifying assumptions are reasonable, as to interpret the results as causal. A first take is to explore the longevity of the data in order to explore time-related characteristics of the effect. Namely, that the effect indeed occurs after the reform, and –as an important signal of our identification strategy to be credible– that the effects we identify cannot be attributed to previous trends of innovation among the treated MNE subsidiaries, before the reforms. This is somewhat empirically challenging in our dataset, given its nature of some reforms being clustered back-to-back in time. Nevertheless, we perform a number of tests, including Montecarlo simulations, to explore dynamic effects of our treatment both before and after reforms. We are able to rule out the existence of pre-trends in knowledge production and find that the effects, indeed, show up in the estimations following the reforms, as expected. See Appendix A for details and summary of these results.

To tease out the mechanisms behind these findings, Table 4 tests the effect of reforms on the patents filed by teams of inventors that include at least one GMI (direct effect), and on patents filed by teams that only include never-movers (spill-over effect). Once again, results are reported for the same three categories of patents. Strikingly, we find very similar effects on patents that directly involve GMIs and patents that do not. The effect of positive reforms is about 3.3% in both groups, for overall patents. The effect of negative reforms is even slightly larger (-14%) on patents filed by teams of non-movers than on the ones produced by teams including GMIs

(-10%). This suggests that mobile inventors generate large spill-overs on the innovation produced by teams of never-movers.

Table 5 reports the results for our four measures of patent quality scaled by the number of patents: generality, originality, radicalness, breakthroughs, and number of citations. For the sake of conciseness, here we only present the results for the aggregate number of patents. Higher inventor mobility overall - our measure of exposure - is not correlated with patent quality, except for a positive relation with radicalness and the number of citations. Positive reforms do not appear to significantly improve the quality of innovations produced, while negative reforms significantly decrease the originality, the radicalness and the number of citations of the patents that are filed. Once again, it appears that barriers to business movements are highly damaging for the quality of innovation produced in the country, and might have long-lasting effects regardless of whether these measures are reversed later on.

One might wonder what is the economic significance of these results. To get a sense of it, we compute some simple back-of-the-envelope calculation to recover how much of the observed growth in patenting over the period is explained by migration policies. We estimate the main model reported in Equation 1 on the number of patents filed by each subsidiary f and recover the estimated effect of the reforms by multiplying β_2 and β_3 by the subsidiary exposure exp_{fct} and the cumulative count of positive and negative reforms respectively ($Pref_{ct}$ and $Nref_{ct}$). We then aggregate the effect of reforms over the entire sample and subtract it from the observed outcomes. This exercise is clearly not a proper counterfactual analysis, since it assumes the absence of spill-overs and general equilibrium effects. However, we think that it can provide a useful benchmark to interpret the magnitude of our results. Figure 2 shows the graph obtained from this exercise. Overall, in the absence of all reforms, the total number of patents filed at the peak in 2013 would have been 28% lower (Figure 2a). If only negative reforms had been avoided, we would have observed 17% more patents in 2013, while if only positive reforms had been avoided we would have observed 45% less patents in 2013 (Figure 2b).

4.3 Robustness tests

We perform a series of robustness tests to ensure the validity of our main results. Tables B3, B4, and B5 in Appendix present the regressions relying on a measure of exposure computed as the mobility of inventors within the MNE observed over the period going from $t-6$ to $t-10$. This procedure gives rise to very similar results in terms of magnitude. The effect of positive reforms on overall patent counts becomes marginally insignificant, but remains significant once we split between teams with and without GMIs. The effect of negative reforms remains significant in all outcomes except for the quality measures, which lose significance.

Tables B6 and B7 in the Appendix perform two placebo tests to ensure that our measure of exposure is not correlated with differential trends in patenting that are unrelated to the reforms. In the first placebo test (Table B6), we randomly assign 47 positive and 14 negative fictitious reforms over the sample of 15 countries and 26 years (following the actual number and types of reforms), and then we run our main specification on this modified dataset. We repeat the operation over 1000 replications, and we report the mean of the three coefficients of interest, as well as the mean and the standard deviation of the standard errors, and find the results lose statistical significance. In the second placebo test (Table B7) we do the same procedure, but we randomly assign 59 fictitious reforms which in turn are also randomly classified as positive or negative, therefore relaxing further the structure of the data by avoiding imposing a fix number of positive and negative events. This exercise, too, result in small and insignificant coefficients associated with exposure interacted with positive and negative pseudo-reforms. Note that in these placebo tests, the exposure coefficient alone remains significantly positive and similar in magnitude to the one obtained in the main analysis, as expected.

Tables B8, B9, B10 and B11 test the effects of introducing positive and negative reform counts in separate regressions, for the main outcomes, the direct effects on patents filed by teams with GMIs, the spill-over effects on patents filed by teams of never-movers, and the quality of patents produced. In this case, the sample is restricted to the countries that experience one or the other type of reforms.[23] The sign and significance of the results are very similar to the ones presented in the main analysis. In the sample of countries that only experience negative reforms, one additional negative policy decreases patenting by a smaller amount (-11% vs -14% obtained in the main analysis). On the contrary, positive reforms are associated with larger gains when they are included alone (+4.6% vs +3.1% in the main analysis). Despite these slight differences in magnitude, the general message remains unchanged: positive reforms increase patent production within a country through additional domestic patents, while negative reforms reduce them through both a decrease in GCPs and a decrease in domestic patents, with the latter being larger than the former. Once again, negative reforms show stronger effects in magnitude compared to positive ones, and the magnitude of direct effects is similar than the spill-overs.

Another robustness test that we perform is to only consider the sub-sample of reforms that affect permanent migration, defined as changing the conditions for migrants staying more than one year in the country. The list is presented in table 1. For this analysis we have to drop Brazil since it does not experience any permanent reform over the period of interest. the results are reported in Tables B12, B13, and B14. Once again, the coefficients are very similar to the ones obtained in the main analysis. The magnitude of the effect associated with positive reforms is slightly larger (+7% on total patents vs +3.1% obtained in the main analysis), while the one associated with negative reforms remains roughly the same (about -13%). Permanent negative reforms maintain their detrimental effect on originality and on citations.

Tables B15, B16 and B17 test the impact of lagging the reforms by one year. Here the coefficients are all extremely similar to the main ones so we do not provide a detailed description. Finally, we test the sensitivity of our results to excluding one country from the sample. Each column of Table B18 reports the effect obtained after the exclusion of one of the 9 countries that account for more than 5 thousands observations in the data, sequentially.[24] Results are presented for the total number of patents (panel A), GCPs (panel B), and domestic patents (panel C). The magnitude of

[23] Positive reform regressions include all the 15 countries except Canada, and the negative reform regressions include Canada, China, Germany, The United Kingdom, Italy, Mexico, The Philippines, Portugal and Taiwan (exclude Brazil, Chile, Spain, India, Japan, and South Korea).

[24] The countries with more than 5 thousands observations in our sample are Canada, China, Germany, United Kingdom, India, Italy, Japan, South Korea and Taiwan.

the effect of positive reforms on total number of patents is very stable across regressions, except for the sample excluding South Korea, where the magnitude doubles in size (goes from 3% in the main sample to 6.3%). This might be explained by the fact that South Korea has the largest number of positive reforms (13), and the marginal effect of one additional reform might be smaller in this case. The coefficients become marginally insignificant in two cases (when either the United Kingdom or Japan are excluded), but the magnitude of the effect remains comparable. Both the magnitude and the significance of the effect of negative reforms on total number of patents remains very stable across all the samples, confirming that the negative effect is the most robust. This is especially true for domestic patents, since the negative effect on GCPs sometimes becomes insignificant.

Section C.1 in the Appendix reports some extensions of the main results, including the heterogeneity of the effect across MNE's size and reform type, and the effects on the extensive margin of patent production. We find that large MNEs experience larger effects for positive reforms, and are not harmed by negative reforms. The opposite is true for small MNEs, which suffer a lot from negative reforms and benefits little from positive ones. Furthermore, the effect of positive reforms is driven by legal changes affecting the volume of newcomers, while the effect of negative reforms is driven by legal changes decreasing the rights of foreign workers in the country. Finally, when we consider the extensive margin, we find that positive reforms increase the likelihood of filing GCPs and decrease the likelihood of filing domestic patents, while negative reforms decrease both the likelihood of filing GCPs and domestic patents.

Section C.2 in the Appendix explores innovation productivity outcomes in the context of our results. We show that while productivity of GMIs increases after they move to their destination countries, migration reforms do not affect the overall number of patents per inventor for the average subsidiary. Moreover, we find that the effect of migration policies on the number of patents filed by each subsidiary is fully explained by changes in the number of inventors that patent there, both GMIs and domestic inventors. That is, consistent with Kerr et al. (2015), we find that by increasing (decreasing) the number of GMIs in the subsidiary, positive (negative) reforms also increase (decrease) the number of non-GMI (or domestic) inventors, suggesting strong complementarity in production between mobile and immobile human capital.

5 Changes in the geography of knowledge production

One of the most important questions that we can answer in our setting is whether human mobility, facilitated or hindered by the migration reforms in our sample, explains shifts in the geography of global knowledge production. Figure 1d shows that, during our period of interest, emerging markets such as China, Korea, Taiwan and India increased drastically their share of total patent production, at the expenses of advanced countries such as Japan, Germany and the United Kingdom. We investigate the role played by mobility policies by estimating our main model on the share of total yearly patents filed by each subsidiary, and by evaluating the heterogeneity of the effect across countries with initially high and low shares of global innovation production. In particular, we measure the initial share of global innovation by computing the total number of patents filed between 1985 and 1990 by each country in our data as a share of the total. We then split the sample in half according to this measure and define those countries above and below the median as "high" and "low", respectively. We then re-estimate our main specification by adding a triple interactions as follows:

$$Y_{fct} = \beta_0 + \beta_1 exp_{fct} + \beta_2 exp_{fct} \times PRef_{ct} + \beta_3 Exp_{fct} \times NRef_{ct} + \beta_4 exp_{fct} \times LIS_c + \beta_5 exp_{fct} \times LIS_c \times PRef_{ct} + \beta_6 exp_{fct} \times LIS_c \times NRef_{ct} + \gamma_{ct} + \delta_{ft} + \epsilon_{fct} \quad (2)$$

Where Y_{fct} captures the share of total patents filed in year t across all countries in the sample coming from subsidiary f in country c, and LIS_c is a binary indicator identifying countries with low initial shares in global patent production. Table 6 reports the results from estimating the baseline model reported in Equation 1 as well as the triple interactions reported in Equation 2. Column (1) of Table 6 shows that positive reforms do not significantly impact the share of total patents filed by a subsidiary, but negative reforms do decrease it significantly. Similar results are found for GCPs and domestic patents when considered separately (Columns (3) and (5)). Interestingly, results are highly heterogeneous across the initial share of innovation. Countries that counted very little in global knowledge production at the beginning of the period gain significantly more following positive migration reforms, while the initial leaders in knowledge production lose significantly more following negative migration reforms. This result highlights how policies affecting the mobility of inventors effectively helped emerging markets to gain importance in the geography of global innovation. These patterns are once again observed for both GCPs and domestic patents (Columns (4) and (6)).

To get a sense of the economic significance of these effects relative to the overall shifts in the distribution of patents, we compute some simple back-of-the-envelope calculations to recover how much of the observed growth in the share of patents filed by emerging markets is explained by migration policies. We follow a similar procedure as for total patents by using our triple interactions model to predict the effect of positive and negative reforms on the share of global patents filed by each subsidiary f located in a country with low initial shares. We then use them to calculate the total effect of reforms on the share of total patents filed by each country c within the low initial share group in year t as follows:

$$\left(\frac{P\hat{A}T_{ct}}{PAT_t}\right) = \sum_{f=1}^{F} exp_{fct}\Big((\beta_2 + \beta_5)PRef_{ct} + (\beta_3 + \beta_6)NRef_{ct}\Big) \tag{3}$$

Finally, we compute the predicted aggregate trends in the geography of innovation in the absence of the migration reforms by subtracting $\frac{P\hat{A}T_{ct}}{PAT_t}$ from the actual share observed in each country $\frac{PAT_{ct}}{PAT_t}$, and aggregating it over all countries with low initial shares. Figure 3a shows that countries with initially low share of patents would have only grown from roughly 5% to 20% of total innovation in the absence of migration reforms, while the actual change that occurs over the period brings them to 50% of total innovation. Figure 3b further distinguishes between the predicted outcome in absence of positive migration reforms and in absence of negative ones, showing that positive reforms have helped substantially these countries to become leading inventors, and if they would have not adopted the negative migration reforms they would have reached up to 60% of patents filed by 2015. These results strongly suggest that policies favoring human mobility have helped emerging markets in their global innovation race. Migration reforms are thus crucial elements to understand the global trends in the geography of innovation observed over the past decades. Figure B4 in the Appendix disaggregates the comparison between actual and predicted trends by country, showing that positive migration reforms generated a particularly large boost for China and Korea.

6 Conclusion

The impressive rise of China and India as destinations for the production of global innovation in the past two decades has often been attributed to MNEs shifting their patenting activity towards these countries. The innovative capacity of multinational enterprises (MNEs) is increasingly recognized to rely on the knowledge of its local subsidiaries. In this context, the cross-border mobility of inventors is highlighted as a key mechanism for global knowledge production by MNEs, but evidence of this relationship remains thin. The purpose of this study is to explore this interrelationship. Specifically, we do so through investigating whether and to what extent MNEs' subsidiary-level investments in innovation change following migration reforms that either ease or reinforce barriers to immigration into the country. We match the full list of business-related migration reforms adopted since 1990 within 15 countries to the patenting activities of the country-level MNE subsidiaries identified in the database of USPTO patents.

We find that pro-business migration reforms significantly increase MNE innovation within a country, especially in terms of domestic patenting, while reforms that discourage migration lead to a significant decline in both domestic patents and GCPs. The effect seems to pass both through a change in innovation produced by teams that directly involve GMIs but also by domestic teams entirely composed of never-movers, which highlights the presence of important spill-overs associated with inventors' mobility. Finally, positive migration reforms contribute to explain the increased importance of emerging markets in global knowledge production, while negative migration reforms were a setback for historical leaders in the innovation race. This finding suggests that policies affecting human mobility have contributed to the observed shift in the geography of innovation towards emerging markets.

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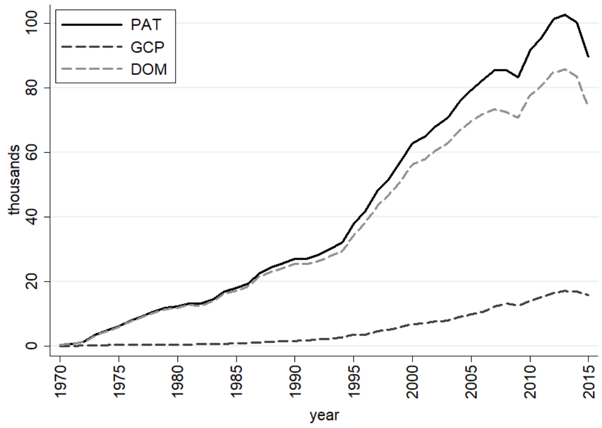
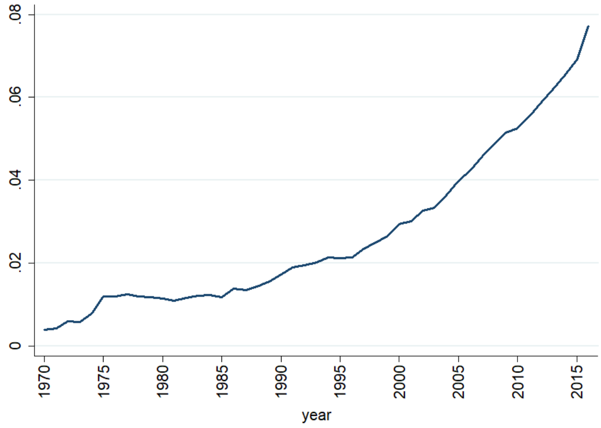
Figure 1: Global trends in patenting and migration

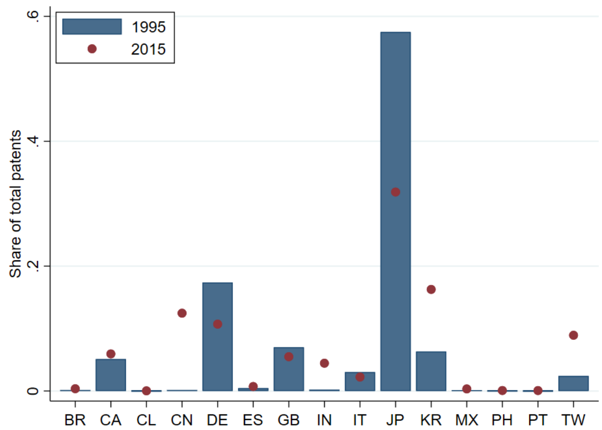
(a) Number of patents



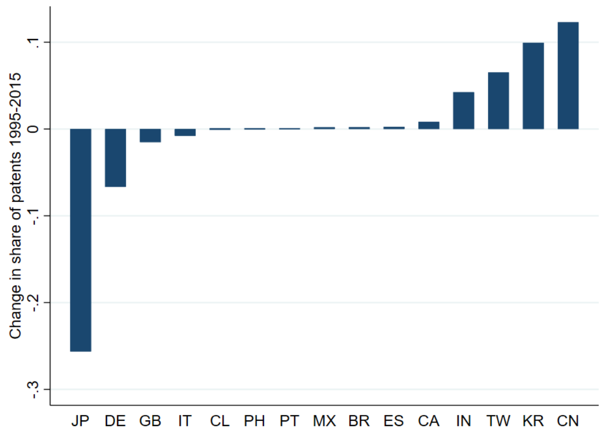
(b) Share of GMIs



(c) Share of global patents by country



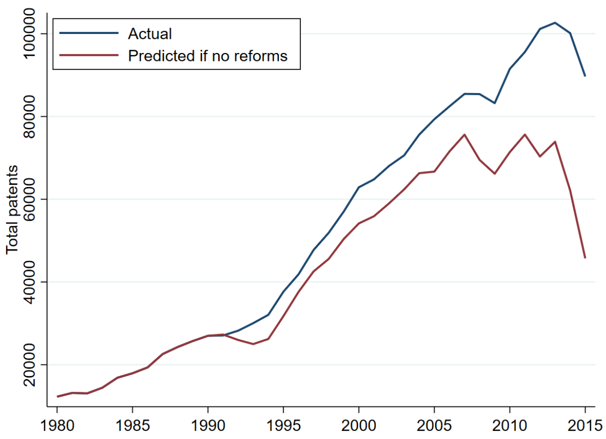
(d) Change in share of global patents by country



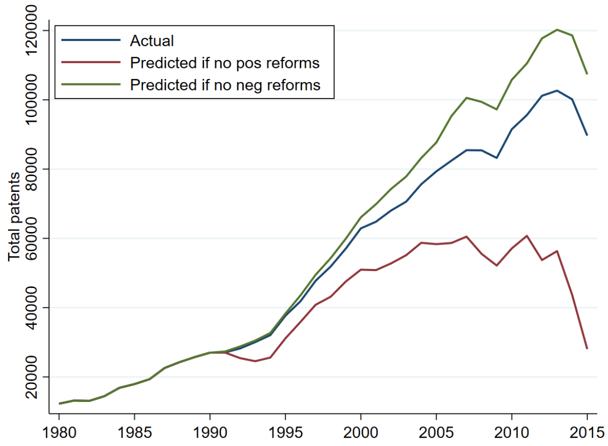
Panel (a) shows the evolution of the total number of patents reported in the USPTO data (solid line), as well as the break-down between domestic patents and GCPs. Panel (b) shows the evolution of the share of global migrant inventors out of the total population of inventors. An inventor is considered as a GMI if he is observed patenting in a different country with respect to the first country of appearance in the data. Panel (c) shows the share of total patents in the sample filed by each country in 1995 and 2015, and Panel (d) shows the change in that share.

Figure 2: Predicted aggregate trends in total patents

(a) Effect of all reforms



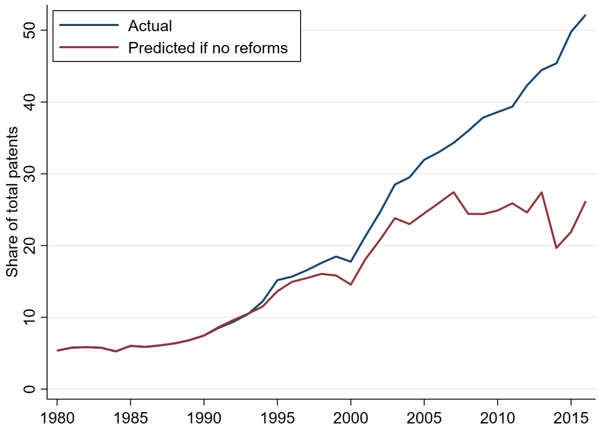
(b) Effect of positive and negative reforms



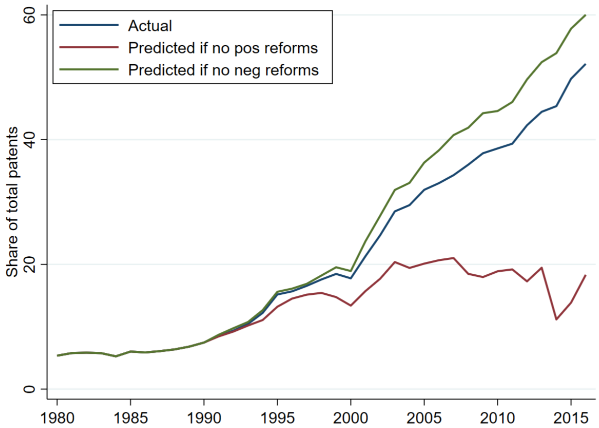
The actual outcomes are the total patents filed in our sample across the period of interest. The predicted outcomes are obtained by subtracting the predicted effect of positive and negative migration reforms to the actual outcomes.

Figure 3: Predicted aggregate trends observed in countries with low initial shares of patents

(a) Effect of all reforms



(b) Effect of positive and negative reforms



The actual outcomes are the share of total patents observed in countries with low initial shares across the period of interest (the 50% of our sample with the lowest initial share of total patents as measured between 1985 and 1990). The predicted outcomes are obtained by subtracting the predicted effect of positive and negative migration reforms to the actual outcomes.

Table 1: List of migration reforms by country

Country	Positive Business Reforms	Negative Business Reforms	Permanent Positive Business Reforms	Permanent Negative Business Reforms
Brazil	2014	-	-	-
Canada	-	2001	-	2001
Chile	2005	-	2005	-
China	1994, 2004, 2008, 2013	1996	1994, 2004, 2008, 2013	1996
Germany	2000, 2005, 2012, 2016	2004	2005, 2012, 2016	-
Spain	1996, 2003, 2009	-	1996, 2003, 2009	-
United Kingdom	2006	1996, 2006	2006	1996, 2006
India	2005, 2016	-	2005	-
Italy	1995, 1998	1991, 1998, 2002	1995, 1998	1991, 1998, 2002
Japan	1992, 1993, 2010, 2012, 2014, 2015	-	1992, 1993, 2010, 2012, 2014	-
Korea	1991, 1992, 1993, 1994, 1995, 1996, 1998, 1999, 2002, 2004, 2007, 2009, 2010	-	1998, 2009, 2010	-
Mexico	2010, 2011, 2014	2012	2010, 2011, 2014	-
Philippines	1996, 2002, 2013	2009, 2012, 2015	1996	2009, 2012, 2015
Portugal	2001, 2012	2003	2001	2003
Taiwan	2014, 2015	1992	2014, 2015	-
Total N. of reforms	47	14	30	11

This table details the year of implementation for each of the 59 reforms enacted over the period of interest and report the subsamble of them that affect stays of 1 year or longer (called "permanent"). The reforms introduced in the United Kingdom in 2006 and in Italy in 1998 have both positive and negative elements, and are thus double-counted in this table.

Table 2: Summary statistics of main outcomes

	Full sample		Low exposure subsidiaries		High exposure subsidiaries	
VARIABLES	mean	(sd)	mean	(sd)	mean	(sd)
N. of patents	14,0	(97,1)	8,0	(35,0)	21,7	(140,7)
N. of GCP	1,9	(7,0)	0,7	(1,4)	3,3	(10,3)
N. of domestic patents	12,2	(94,2)	7,3	(34,8)	18,4	(136,3)
Patents by teams with at least one GMI						
N. of patents	3,3	(27,5)	1,5	(9,5)	5,6	(39,9)
N. of GCP	1,0	(4,8)	0,3	(1,0)	1,9	(7,0)
N. of domestic patents	2,3	(24,8)	1,2	(9,3)	3,7	(36,0)
Patents by teams without any GMI						
N. of patents	10,7	(75,9)	6,5	(29,4)	16,0	(109,4)
N. of GCP	0,8	(2,9)	0,4	(0,9)	1,4	(4,2)
N. of domestic patents	9,9	(75,1)	6,1	(29,3)	14,7	(108,1)
Quality of patents						
Average patent generality	0.50	(0.23)	0.50	(0.23)	0.50	(0.22)
Average patent originality	0.76	(0.16)	0.76	(0.17)	0.77	(0.15)
Average patent radicalness	0.37	(0.22)	0.37	(0.22)	0.38	(0.21)
Share of breakthrough patents	0.007	(0.072)	0.006	(0.069)	0.008	(0.076)
N. of citations per patent	11.6	(28.3)	10.7	(26.8)	12.6	(29.8)
Global migrant inventors						
N. of GMIs	1,7	(10,8)	0,7	(3,4)	2,8	(15,3)
Share of GMIs	0,17	(0,30)	0,12	(0,27)	0,22	(0,33)
N. observations	127 543		71575		55968	

Summary statistics computed over the sample of subsidiaries, identified by MNE x country pair, in the sample spanning from 1990 to 2016.

Table 3: Main results

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Exposure x positive reforms	0.0314**	0.00734	0.0338*
	(0.0157)	(0.00664)	(0.0177)
Exposure x negative reforms	-0.138***	-0.0350**	-0.144***
	(0.0299)	(0.0167)	(0.0350)
Exposure	0.657***	0.194***	0.794***
	(0.0498)	(0.0258)	(0.0572)
Observations	70,969	70,969	70,969
R-squared	0.508	0.562	0.500

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1.

Table 4: Direct and spill-over effects

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Panel A: Patents by teams with at least one GMI			
Exposure x positive reforms	0.0326**	0.00658	0.0359**
	(0.0138)	(0.00628)	(0.0152)
Exposure x negative reforms	-0.0975***	-0.0343**	-0.0987***
	(0.0269)	(0.0167)	(0.0301)
Exposure	0.421***	0.176***	0.477***
	(0.0441)	(0.0262)	(0.0495)
Observations	70,969	70,969	70,969
R-squared	0.535	0.584	0.449
Panel B: Patents by teams with no GMIs			
Exposure x positive reforms	0.0341**	0.00386	0.0358**
	(0.0166)	(0.00532)	(0.0174)
Exposure x negative reforms	-0.142***	-0.0204*	-0.148***
	(0.0320)	(0.0122)	(0.0338)
Exposure	0.727***	0.123***	0.775***
	(0.0545)	(0.0197)	(0.0578)
Observations	70,969	70,969	70,969
R-squared	0.497	0.517	0.495

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1. Outcomes are divided into teams where at least one inventor is a GMI (has patented in a different country in earlier years), and teams of never-moving inventors.

Table 5: Results on patent quality

	(1)	(2)	(3)	(4)	(5)
	asinh generality per patent	asinh originality per patent	asinh radicalness per patent	asinh share of breakthrough patents	asinh citations per patent
VARIABLES	OLS	OLS	OLS	OLS	OLS
Exposure x positive reforms	0.000326	-0.000392	-0.000617	-9.82e-05	0.00151
	(0.000469)	(0.000308)	(0.000451)	(0.000151)	(0.00331)
Exposure x negative reforms	0.000250	-0.00256**	-0.00378**	-0.000742	-0.0228**
	(0.00172)	(0.00100)	(0.00160)	(0.000480)	(0.0100)
Exposure	-0.00177	0.00165	0.00458**	3.33e-05	0.0804***
	(0.00192)	(0.00116)	(0.00181)	(0.000630)	(0.0121)
Observations	53,196	60,823	60,830	61,518	61,518
R-squared	0.619	0.622	0.583	0.487	0.671

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1. Columns (1), (2) and (3) weight the count of the number of patents by the generality, originality and radicalness coefficients, respectively and then divide them by the patent count. Column (4) computes the share of patents that are considered breakthrough. Column (5) computes the number of citations per patent.

Table 6: Effect on geography of knowledge production

	(1)	(2)	(3)	(4)	(5)	(6)
	Share of total patents filed by subsid.		Share of total GCPs filed by subsid.		Share of total dom. patents filed by subsid.	
VARIABLES	OLS	OLS	OLS	OLS	OLS	OLS
Exposure	0.0739***	0.118***	0.0258***	0.0478***	0.0786***	0.123***
	(0.0217)	(0.0313)	(0.00744)	(0.0136)	(0.0235)	(0.0330)
Exposure x low initial share		-0.0815***		-0.0371***		-0.0839***
		(0.0294)		(0.0135)		(0.0310)
Exposure x positive reforms	0.00644	-0.0107*	-0.000946	-0.0101***	0.00810	-0.00917
	(0.00597)	(0.00588)	(0.00152)	(0.00340)	(0.00678)	(0.00618)
Exposure x negative reforms	-0.0279***	-0.0459***	-0.00869**	-0.0183***	-0.0295***	-0.0478***
	(0.0105)	(0.0143)	(0.00393)	(0.00626)	(0.0113)	(0.0151)
Exposure x positive reforms x low initial share		0.0216**		0.0114***		0.0218**
		(0.00873)		(0.00369)		(0.00961)
Exposure x negative reforms x low initial share		0.0389**		0.0180***		0.0401**
		(0.0152)		(0.00639)		(0.0162)
Observations	70,969	70,969	70,969	70,969	70,969	70,969
R-squared	0.335	0.339	0.424	0.427	0.332	0.335

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1. The outcomes measure the share of total patents, GCPs, and domestic patents produced in a year filed by each subsidiary. Low initial share identifies the 50% of the sample with the lowest share of global patents observed over the period 1985-1990.

Online Appendix for

Human Mobility and the Globalization of Knowledge Production: Causal Evidence from Multinational Enterprises

A Validity of the Main Assumptions

The cardinal assumption of difference-in-differences estimations, is the common trend hypothesis. Namely, it supposes that the treated group would have evolved following the same trend of the control group in the absence of the treatment event. In our context, this assumption supposes that subsidiaries with different levels of exposure to the reform would have shows similar trends in patenting in the absence of the reforms. This hypothesis is untestable, given the fact that we cannot observe what would have happened in the years following a reform in the absence of the latter. What is typically shown in the literature to assess the plausibility of this assumption are the trends observed before the reform: if treated and control subsidiaries evolved following similar patterns prior to the introduction of the policy, we can reasonably imagine that they would have continue doing so if the reform would not have been introduced. In our context, we can test that the trends in patenting were uncorrelated with reform exposure during the years that preceded the first reform in each country by estimating the following model:

$$Y_{fct} = \beta_0 + \beta_1 exp_{fct} + \sum_{k=-3}^{-1} 1_{\{t_{Ref_c}+k=t\}} \tau_k exp_{fct} + \gamma_{ct} + \delta_{ft} + \epsilon_{fct} \tag{A1}$$

where $1_{\{t_{Ref_c}+k=t\}}$ is a series of dummies identifying the 3 years preceding the first reform in a given country c, exp_{fct} captures the level of exposure of each subsidiary in the country, and τ_k

recovers the differential trends correlated with exposure relative to t-3, which is normalized to zero. We estimate this model separately for positive and negative reforms, restricting each sample to the countries that experience at least one reform of that type.

Results for the three main outcomes are shows in figure A1. Given that none of the coefficients is statistically different from zero, we can conclude that subsidiaries differently exposed to the reforms followed similar patenting trends prior to the first policy change in our sample. It is common practice to show the coefficients associated with the years following the reform as well, in order to get a sense of the dynamic effects at play. In our context, given the presence of subsequent reform within the same country that are sometimes clustered in time, we have to adopt a more complex strategy to show the dynamic effects. The latter is presented in subsection A.1.

The second central assumption in our strategy is that the average treatment effect of a given reform type is equivalent across events, which means that the magnitude of the effect of the first reform in a given country is comparable to the second reform, the second is comparable to the third, and so forth. To test this assumption we estimate the following model:

$$Y_{fct} = \beta_0 + \beta_1 exp_{fct} + \sum_{r=1}^{3} \alpha_r Ref_{ct}^{r} \times exp_{fct} + \gamma_{ct} + \delta_{ft} + \epsilon_{fct} \tag{A2}$$

where r indexes up to three consecutive reforms of a given type (positive or negative) in a given country, Ref_{ct}^{r} identifies the period in country c after reform r and prior to reform $r+1$, and α_r recovers the distinct effect of each subsequent reform from the first to the third.[25] The regression is run separately for positive and negative reforms on the sample of countries that experience at least one of them, and on the sample of years preceding the fourth reform of the same type within each country.

[25]We limit ourselves to 3 consecutive reforms because the sample of countries experiencing more than 3 reforms of the same type becomes very small.

The recovered coefficients are reported in Figure A2. What we can observe is that the effect is slightly increasing in magnitude, with the second positive reform having slightly larger effect than the first, and the third negative reform having slightly larger effects than the second. Nonetheless, the 95% confidence intervals overlap, suggesting that the effects are comparable in terms of magnitude.

A.1 Dynamic Effects

The standard model used to recover the dynamic treatment effects is the following:

$$Y_{fct} = \beta_0 + \beta_1 exp_{fct} + \sum_{k=-3}^{+3} 1_{\{t_{PRef_c}+k=t\}} \alpha_k exp_{fct} + \sum_{k=-3}^{+3} 1_{\{t_{NRef_c}+k=t\}} \theta_k exp_{fct} + \gamma_{ct} + \delta_{ft} + \epsilon_{fct} \quad \text{(A3)}$$

where k indexes time to the nearest reform, $1(t_{PRef_c} + k = t)$ is a series of indicator variables indexing observations k periods before or after a positive reform event, and $1(t_{NRef_c} + k = t)$ are the equivalent for negative reforms. exp_{fct} represents our exposure measure. Here, α_k and θ_k identify the dynamic marginal treatment effects of positive and negative reforms at event-time k relative to an omitted baseline period (the year prior to reform enactment). This estimate can be thought of as a by-year estimate of the β_2 coefficients in Equation 1 that comes at the expense of omitting information on reform events' links to all but the most proximate years.

In the ideal setting, we would estimate the model reported in Equation A3 on the full sample, assigning the timing with respect to the closer reform. Nevertheless, in our case the high frequency of reforms observed in certain countries makes it really difficult to distinguish between pre- and post- periods. We thus adopt an alternative strategy: We perform a Montecarlo simulation in which we randomly draw 1000 times one single positive and one single negative reform for each country, which we use to estimate Equation A3. We then take the average over the 1000 different

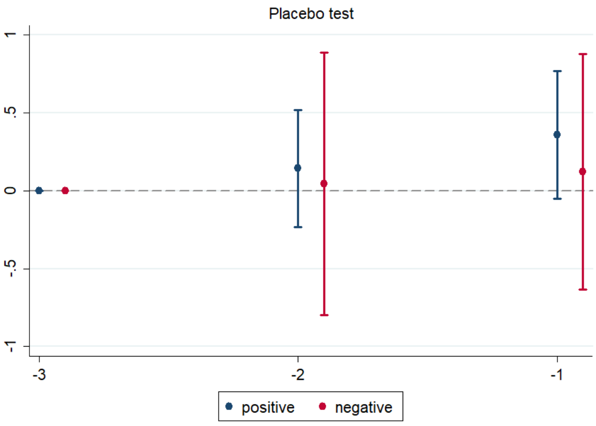
α_k and θ_k that we obtain, and we compute bootstrapped standard errors.[26]

Figure A3 plots the point estimates and corresponding 90% confidence intervals of α_k and θ_k for the three years leading to a reform and the three years following it. The year preceding the reform is used as reference point. Figure A3a shows that patent production in subsidiaries with different levels of exposure followed the same exact trends in the years preceding a positive reform and, if anything, they showed slightly higher growth in the years preceding a negative reform. After the implementation of a positive policy, there is an increase in the number of patents filed by the subsidiary, but the effect on individual post period years is not significant. After a negative reform, most exposed subsidiaries see a decline in patents compared to the rest, which becomes significant at t+3. When we disentangle between GCPs and domestic patents (Figure A3b and Figure A3c), we find no effect of positive reforms on GCPs, and generally a larger effect in magnitude on domestic patents. These results are broadly consistent with the main (static) analysis, but with the difference that the majority of the coefficients on individual post-period years are insignificant. This might be explained by the fact that positive reforms have a significant effect if all post-reform years are considered together (including long term effects), but not if individual years are considered separately. This exercise also underlines the difficulty to perform the standard event study analysis in a context including multiple reforms clustered in time.

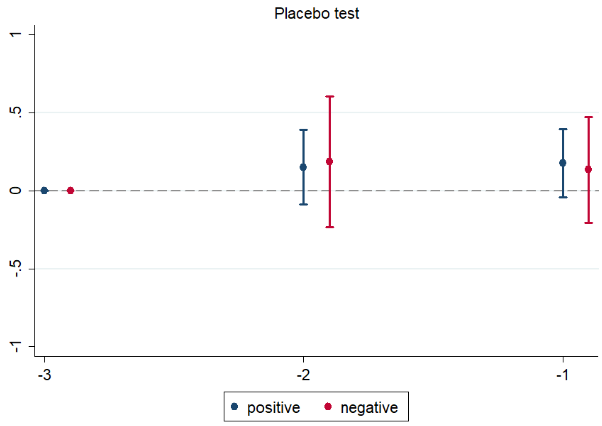
[26]In countries where both positive and negative reforms take place, each time we draw one from each of the two types. For the others, we only draw from the reform type that they have. In order to maintain all the observations in the regressions, for countries without positive reforms we set all the time-to-reform dummies to zero, and we do the same for countries without negative reforms.

Figure A1: Test for pre-trends

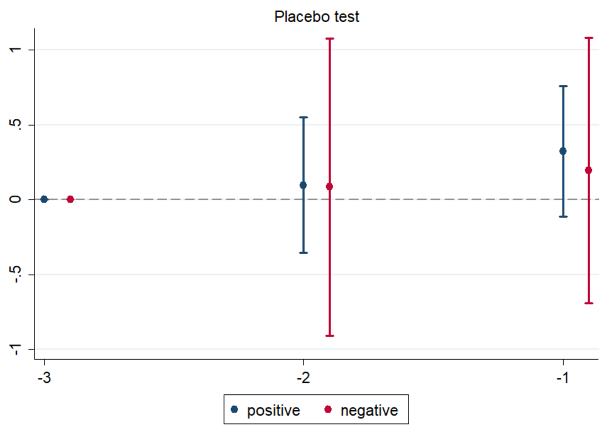
(a) asinh Patents



(b) asinh GCPs



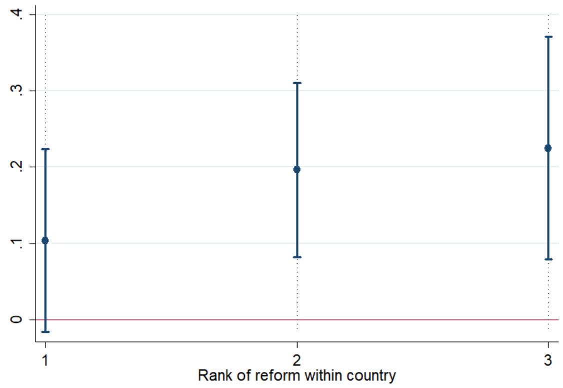
(c) asinh Domestic Patents



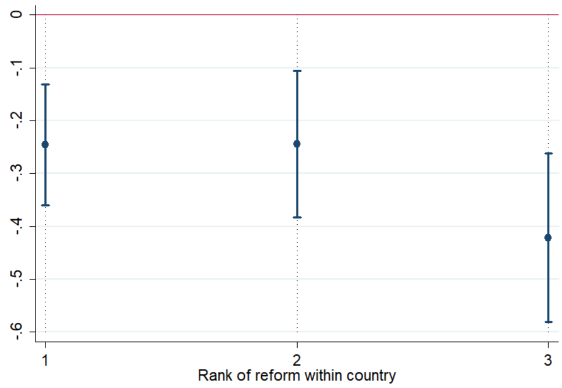
These graphs plot the dynamic effects obtained by running Equation A1 on the 3 years preceding the first reform in each country. Time t-3 is normalized to zero. The model is estimated separately for positive and negative reforms. The bars represent the 95% confidence intervals.

Figure A2: Test for equivalence of effect across subsequent reforms

(a) asinh Patents, subsequent positive reforms



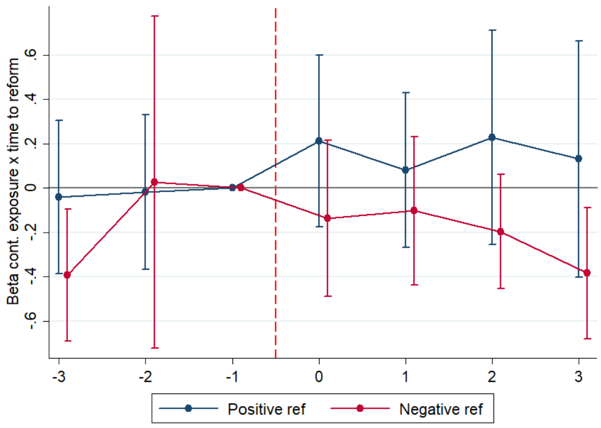
(b) asinh Patents, subsequent negative reforms



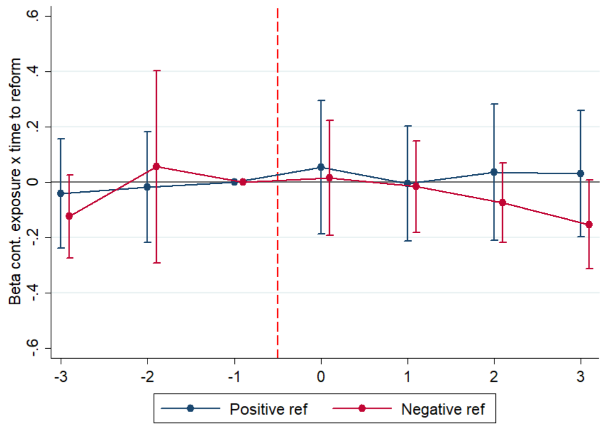
These graphs plot the separate effect of the 1st, 2nd and 3rd reform taking place in a country obtained by running Equation A2 on the sample cut before the 4th subsequent reform. The model is estimated separately for positive and negative reforms. The bars represent the 95% confidence intervals.

Figure A3: Dynamic effect of reforms

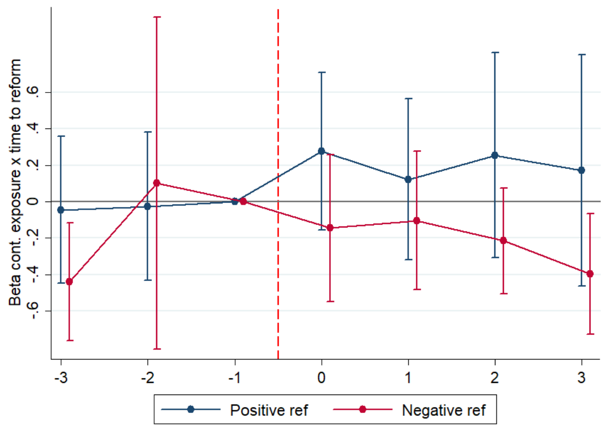
(a) asinh Patents



(b) asinh GCPs



(c) asinh Domestic Patents



These graphs plot the dynamic effects obtained by running Equation A3 on the 3 years preceding and the 3 years following the reforms, for total number of patents (panel a), GCPs (panel b)), and domestic patents (panel c)). The bars represent the 90% confidence intervals. Instead of estimating the model on the full sample of reforms, the graph is obtained by running a Montecarlo simulation on 1000 random samples where one positive and one negative reform are picked for each country, and by averaging the effect over all of them.

B Additional Tables and Figures

B.1 Tables

Table B1 displays the frequency of subsidiaries and patents of the different types across the reform countries during the years of the sample. There is substantial heterogeneity among the presence of MNE subsidiaries across the countries, with Western countries (e.g. Canada, Germany, the United Kingdom, etc.) showing the largest frequency of MNE implantation, followed by Asian countries (e.g. Japan, China, Taiwan). Additionally, certain countries produce global collaborative patents at greater rates than domestic patents and at significantly higher rates than those found in Kerr and Kerr (2018). It is the case for Chile, Spain, Mexico, the Philippines and Portugal, thus underlining a wide heterogeneity in the knowledge production strategies.

Table B2 tests the correlation between the cumulative count of reforms and the arcsinh-transformed number of GMIs in the subsidiary. Column (1) reports the unconditional coefficients, while columns (2) and (3) add controls for year fixed effects, and year and country fixed effects respectively. Finally, column (4) and (5) test the first stage obtained from the main specification displayed in Equation 1, using both contemporary and historical exposure. Results show that one additional positive reform increases the number of GMIs by about 5.3%, while one additional negative reform decreases it by about 2.8%. With the addition of fixed effects, the coefficient becomes smaller for positive reforms, while it becomes larger for negative reforms. Finally, using our main specification, we find that subsidiaries that are one standard deviation more exposed, have on average 35% more GMIs than the mean subsidiary. One additional positive reform increments that value by 3%, while one additional negative reform decreases it by almost 8%. Taken together, these results confirm that migration reforms do affect the international mobility of inventors. In the next section, we analyze how this affects the location of knowledge production.

Tables B3, B4, and B5 present the regressions relying on a measure of exposure computed as the mobility of inventors within the MNE observed over the period going from $t-6$ to $t-10$. This procedure gives rise to very similar results in terms of magnitude as the main ones presented in the paper. The effect of positive reforms on overall patent counts becomes marginally insignificant, but remains significant once we split between teams with and without GMIs. The effect of negative reforms remains significant in all outcomes except for the quality measures, which lose significance.

Tables B6 and B7 perform two placebo tests to ensure that our measure of exposure is not correlated with differential trends in patenting that are unrelated to the reforms. In the first placebo test (Table B6), we randomly assign 47 positive and 14 negative fictitious reforms over the sample of 15 countries and 26 years (following the actual number and types of reforms), and then we run our main specification on this modified dataset. We repeat the operation over 1000 replications, and we report the mean of the three coefficients of interest, as well as the mean and the standard deviation of the standard errors, and find the results lose statistical significance. In the second placebo test (Table B7) we do the same procedure, but we randomly assign 59 fictitious reforms which in turn are also randomly classified as positive or negative, therefore relaxing further the structure of the data by avoiding imposing a fix number of positive and negative events. This exercise, too, result in small and insignificant coefficients associated with exposure interacted with positive and negative pseudo-reforms. Note that in these placebo tests, the exposure coefficient alone remains significantly positive and similar in magnitude to the one obtained in the main analysis, as expected.

Tables B8, B9, B10 and B11 test the effects of introducing positive and negative reform counts in separate regressions. In this case, the sample is restricted to the countries that experience one or the other type of reforms. The sign and significance of the results are very similar to the ones presented in the main analysis. In the sample of countries that only experience negative reforms, one additional negative policy decreases patenting by a smaller amount (-11% vs -14% obtained in the main analysis). On the contrary, positive reforms are associated with larger gains when they are included alone (+4.6% vs +3.1% in the main analysis). Despite these slight differences in magnitude, the general message remains unchanged.

Tables B12, B13, and B14 present the results obtained if we only consider the sub-sample of reforms that affect permanent migration, defined as changing the conditions for migrants staying more than one year in the country. For this analysis we have to drop Brazil since it does not experience any permanent reform over the period of interest. Once again, the coefficients are very similar to the ones obtained in the main analysis. The magnitude of the effect associated with positive reforms is slightly larger (+7% on total patents vs +3.1% obtained in the main analysis), while the one associated with negative reforms remains roughly the same (about -13%). Permanent negative reforms maintain their detrimental effect on originality and on citations.

Tables B15, B16 and B17 test the impact of lagging the reforms by one year. Here the coefficients are all extremely similar to the main ones, so we do not provide a detailed description.

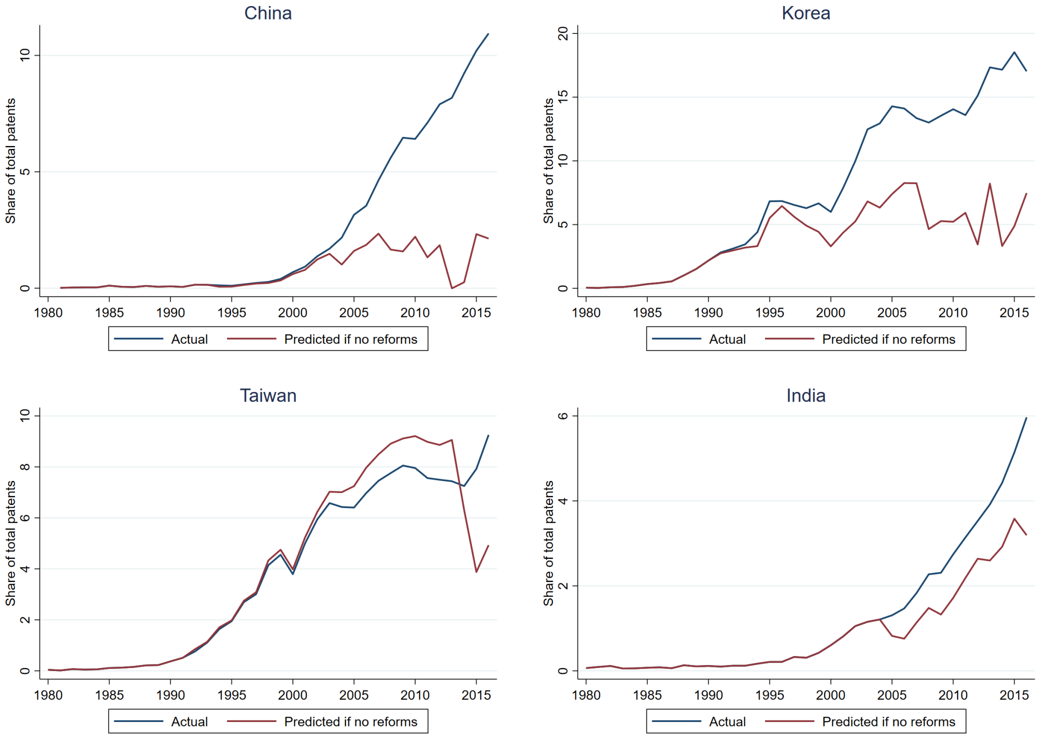
Table B18 tests the sensitivity of our results to excluding one country from the sample. Each column reports the effect obtained after the exclusion of one of the 9 countries that account for more than 5 thousands observations in the data, sequentially. Results are presented for the total number of patents (panel A), GCPs (panel B), and domestic patents (panel C). The magnitude of the effect of positive reforms on total number of patents is very stable across regressions, except for the sample excluding South Korea, where the magnitude doubles in size (goes from 3% in the main sample to 6.3%). This might be explained by the fact that South Korea has the largest number of positive reforms (13), and the marginal effect of one additional reform might be smaller in this case. The coefficients become marginally insignificant in two cases (when either the United Kingdom or Japan are excluded), but the magnitude of the effect remains comparable. Both the magnitude and the significance of the effect of negative reforms on total number of patents remains very stable across all the samples, confirming that the negative effect is the most robust. This is especially true for domestic patents, since the negative effect on GCPs sometimes becomes insignificant.

B.2 Figures

Figure B4 shows how much countries with initially low share of patents would have grown in the absence of migration reforms, comparing it to the actual change that occurs over the period.

Positive migration reforms generated a particularly large boost for China and Korea, while the counterfactual is more similar to the observed trend in innovation observed in Taiwan and India.

Figure B4: Predicted trends in share of global patents after subtracting the effect of reforms



The actual outcomes are the share of total patents observed in each country across the period of interest. The predicted outcomes are obtained by subtracting the predicted effect of positive and negative migration reforms to the actual outcomes. We select the countries in the low-initial share group that have a large number of observations.

Table B1: Summary of patents by country

	N. of patents		N. of GCP		N. of domestic patents		N. Obs
Country	Mean	sd	Mean	sd	Mean	sd	count
Brazil	2,29	(3,76)	1,30	(1,99)	0,99	(2,62)	1718
Canada	4,72	(19,77)	1,82	(6,24)	2,90	(15,31)	15640
Chile	1,29	(0,78)	0,87	(0,83)	0,42	(0,73)	246
China	8,47	(49,58)	2,80	(10,17)	5,67	(45,05)	9435
Germany	9,31	(39,02)	2,04	(7,12)	7,27	(34,24)	27043
Spain	2,44	(4,86)	1,33	(2,23)	1,12	(3,40)	3657
United Kingdom	4,66	(11,38)	1,78	(4,37)	2,88	(8,72)	21617
India	7,28	(26,46)	3,55	(14,36)	3,73	(13,97)	5234
Italy	3,97	(11,36)	1,18	(2,52)	2,79	(10,18)	8728
Japan	43,85	(177,15)	1,33	(3,88)	42,52	(174,92)	19729
Korea	42,83	(297,11)	1,78	(12,06)	41,04	(286,71)	5032
Mexico	2,20	(4,35)	1,29	(1,98)	0,91	(3,13)	1197
Philippines	2,37	(2,48)	1,38	(1,68)	0,99	(1,78)	416
Portugal	1,39	(0,92)	0,96	(0,82)	0,42	(0,89)	496
Taiwan	14,87	(66,19)	1,90	(9,96)	12,97	(60,50)	7356

Summary statistics computed for the sample of subsidiaries belonging to an MNE over the period spanning from 1990 to 2016.

Table B2: First stage regressions

	(1)	(2)	(3)	(4)	(5)
			asinh N. of GMIs		
VARIABLES	OLS	OLS	OLS	OLS main Exp.	OLS Hist. Exp.
Positive business reform	0.0527***	0.0291***	0.0179***		
	(0.00410)	(0.00474)	(0.00528)		
Negative business reform	-0.0279***	-0.101***	-0.0734***		
	(0.00743)	(0.00831)	(0.0108)		
Exposure x positive business reform				0.0311**	0.0276**
				(0.0122)	(0.0132)
Exposure x negative business reform				-0.0787***	-0.0817***
				(0.0247)	(0.0212)
Exposure				0.340***	0.376***
				(0.0400)	(0.0401)
Observations	127,543	127,543	127,543	70,969	70,969
R-squared	0.020	0.036	0.069	0.488	0.495
Year FE		✓	✓		
Country FE			✓		
MNE x year FE				✓	✓
Country x year FE				✓	✓

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. Period of analysis: 1990-2015. Subsequent columns add additional levels of controls. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Historical exposure is computed in the same way but over the period going from 5 to 10 years prior to the observation.

Table B3: Main results using historic exposure

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	hist. exp	hist. exp	hist. exp
Exposure x positive reforms	0.0285	0.00633	0.0315
	(0.0177)	(0.00906)	(0.0198)
Exposure x negative reforms	-0.128***	-0.0327**	-0.134***
	(0.0254)	(0.0155)	(0.0299)
Exposure	0.615***	0.211***	0.727***
	(0.0496)	(0.0297)	(0.0567)
Observations	70,969	70,969	70,969
R-squared	0.505	0.565	0.495

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Historical exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the period going from 5 to 10 years prior to the observation, and then standardized to have mean 0 and standard deviation of 1.

Table B4: Direct and spill-over effects using historic exposure

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	hist. exp	hist. exp	hist. exp
Panel A: Patents by teams with at least one GMI			
Exposure x positive reforms	0.0287*	0.00631	0.0321*
	(0.0158)	(0.00857)	(0.0174)
Exposure x negative reforms	-0.0907***	-0.0313**	-0.101***
	(0.0232)	(0.0160)	(0.0263)
Exposure	0.436***	0.190***	0.489***
	(0.0452)	(0.0308)	(0.0510)
Observations	70,969	70,969	70,969
R-squared	0.539	0.586	0.453
Panel B: Patents by teams with no GMIs			
Exposure x positive reforms	0.0324*	0.00398	0.0340*
	(0.0183)	(0.00749)	(0.0192)
Exposure x negative reforms	-0.144***	-0.0176	-0.146***
	(0.0272)	(0.0123)	(0.0286)
Exposure	0.662***	0.142***	0.704***
	(0.0543)	(0.0248)	(0.0575)
Observations	70,969	70,969	70,969
R-squared	0.491	0.519	0.488

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Historical exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the period going from 5 to 10 years prior to the observation, and then standardized to have mean 0 and standard deviation of 1. Outcomes are divided into teams where at least one inventor is a migrant (has patented in a different country in earlier years), and teams of never-moving inventors.

Table B5: Effects on patent quality using historic exposure

	(1)	(2)	(3)	(4)	(5)
	asinh generality per patent	asinh originality per patent	asinh radicalness per patent	asinh share of breakthrough patents	asinh citations per patents
VARIABLES	hist. exp	hist. exp	hist. exp	hist. exp	cont. exp
Exposure x positive reforms	0.000622	-0.000273	-2.15e-05	9.78e-05	0.00219
	(0.000521)	(0.000266)	(0.000482)	(0.000235)	(0.00347)
Exposure x negative reforms	0.00120	7.31e-05	0.000137	-0.000370	-0.0107
	(0.00158)	(0.000871)	(0.00145)	(0.000514)	(0.00935)
Exposure	0.000329	0.000760	0.00243	-0.00114	0.0594***
	(0.00193)	(0.00112)	(0.00175)	(0.00107)	(0.0130)
Observations	53,196	60,823	60,830	61,518	61,518
R-squared	0.619	0.622	0.583	0.487	0.671

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Historical exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the period going from 5 to 10 years prior to the observation, and then standardized to have mean 0 and standard deviation of 1. Columns (1), (2) and (3) weight the count of the number of patents by the generality, originality and radicalness coefficients, respectively and then divide them by the patent count. Column (4) computes the share of patents that are considered breakthrough. Column (5) computes the number of citations per patent.

Table B6: Placebo Test 1

	asinh N. migrant inventors	asinh N. of patents	asinh N. of GCPs	asinh N. of domestic patents
VARIABLES	mn coef / (mn se) / [std se]	mn coef / (mn se) / [std se]	mn coef / (mn se) / [std se]	mn coef / (mn se) / [std se]
Exposure x Placebo positive reform	0,002	-0,013	-0,003	-0,011
	(0,014)	(0,017)	(0,009)	(0,020)
	[0,028]	[0,042]	[0,013]	[0,043]
Exposure x Placebo negative reform	-0,002	-0,016	-0,005	-0,015
	(0,028)	(0,035)	(0,018)	(0,041)
	[0,064]	[0,093]	[0,030]	[0,097]
Exposure	0,345	0,658	0,192	0,794
	(0,040)***	(0,050)***	(0,026)***	(0,057)***
	[0,055]***	[0,080]***	[0,024]***	[0,083]***

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2015. Continuous exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1. Results obtained over 1000 replications where 47 positive reforms and 14 negative reforms are selected randomly over the 14 countries and 25 years of interest. We report the average beta coefficient, the average standard error and the standard deviation of the standard errors.

Table B7: Placebo Test 2

	asinh N. migrant inventors	asinh N. of patents	asinh N. of GCPs	asinh N. of domestic patents
VARIABLES	mn coef / (mn se) / [std se]	mn coef / (mn se) / [std se]	mn coef / (mn se) / [std se]	mn coef / (mn se) / [std se]
Exposure x Placebo positive reform	0,000	-0,015	-0,004	-0,013
	(0,018)	(0,023)	(0,012)	(0,027)
	[0,038]	[0,055]	[0,017]	[0,058]
Exposure x Placebo negative reform	0,001	-0,013	-0,004	-0,012
	(0,018)	(0,023)	(0,012)	(0,027)
	[0,040]	[0,058]	[0,018]	[0,060]
Exposure	0,347	0,660	0,193	0,796
	(0,040)***	(0,050)***	(0,026)***	(0,057)***
	[0,054]***	[0,077]***	[0,024]***	[0,081]***

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2015. Continuous exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years. Results obtained over 1000 replications where 59 reforms are selected randomly over the 14 countries and 25 years of interest, and then randomly assigned into positive or negative. We report the average beta coefficient, the average standard error and the standard deviation of the standard errors.

Table B8: Main results of positive and negative reforms separately

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Panel A: Positive reforms only			
Exposure x positive reforms	0.0463**	0.0110	0.0516**
	(0.0205)	(0.00902)	(0.0232)
Exposure	0.632***	0.194***	0.771***
	(0.0532)	(0.0282)	(0.0612)
Observations	57,697	57,697	57,697
R-squared	0.521	0.573	0.516
Panel B: Negative reforms only			
Exposure x negative reforms	-0.113***	-0.0630***	-0.131***
	(0.0349)	(0.0225)	(0.0418)
Exposure	0.501***	0.200***	0.639***
	(0.0629)	(0.0378)	(0.0739)
Observations	44,435	44,435	44,435
R-squared	0.555	0.611	0.528

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Panel A estimates the effect of positive reforms on the sample of countries that experience at least one of them, while Panel B does the same for negative reforms.

Table B9: Direct effects with positive and negative reforms separately

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Panel A: Positive reforms only			
Exposure x positive reforms	0.0467***	0.0100	0.0538***
	(0.0181)	(0.00853)	(0.0201)
Exposure	0.398***	0.178***	0.448***
	(0.0482)	(0.0277)	(0.0547)
Observations	57,697	57,697	57,697
R-squared	0.542	0.590	0.464
Panel B: Negative reforms only			
Exposure x negative reforms	-0.0895***	-0.0616***	-0.0990***
	(0.0326)	(0.0225)	(0.0350)
Exposure	0.332***	0.181***	0.401***
	(0.0571)	(0.0371)	(0.0648)
Observations	44,435	44,435	44,435
R-squared	0.592	0.633	0.481

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Panel A estimates the effect of positive reforms on the sample of countries that experience at least one of them, while Panel B does the same for negative reforms.

Table B10: Spill-over effects with positive and negative reforms separately

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Panel A: Positive reforms only			
Exposure x positive reforms	0.0467**	0.00556	0.0493**
	(0.0213)	(0.00733)	(0.0222)
Exposure	0.716***	0.123***	0.766***
	(0.0567)	(0.0232)	(0.0593)
Observations	57,697	57,697	57,697
R-squared	0.509	0.527	0.511
Panel B: Negative reforms only			
Exposure x negative reforms	-0.109***	-0.0548***	-0.113***
	(0.0372)	(0.0179)	(0.0398)
Exposure	0.564***	0.154***	0.604***
	(0.0700)	(0.0312)	(0.0743)
Observations	44,435	44,435	44,435
R-squared	0.542	0.569	0.520

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Panel A estimates the effect of positive reforms on the sample of countries that experience at least one of them, while Panel B does the same for negative reforms.

Table B11: Patent quality with positive and negative reforms separately

	(1)	(2)	(3)	(4)	(5)
	asinh generality per patent	asinh originality per patent	asinh radicalness per patent	asinh share of breakthrough patents	asinh citations per patents
VARIABLES	OLS	OLS	OLS	OLS	OLS
Panel A: Positive reforms only					
Exposure x positive reforms	0.000216	-0.000307	-0.000557	-2.00e-05	0.00262
	(0.000651)	(0.000400)	(0.000567)	(0.000193)	(0.00437)
Exposure	-0.00103	-0.000280	0.00245	-0.000363	0.0730***
	(0.00184)	(0.00117)	(0.00183)	(0.000835)	(0.0124)
Observations	42,798	49,187	49,194	49,752	49,752
R-squared	0.624	0.628	0.585	0.477	0.672
Panel B: Negative reforms only					
Exposure x negative reforms	-0.000484	-0.00321**	-0.000537	-0.000138	-0.0338**
	(0.00293)	(0.00148)	(0.00243)	(0.000515)	(0.0148)
Exposure	-0.000396	0.00300*	0.00197	-0.00149	0.0790***
	(0.00347)	(0.00180)	(0.00301)	(0.00128)	(0.0194)
Observations	33,177	37,971	37,971	38,336	38,336
R-squared	0.648	0.654	0.616	0.528	0.701

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Panel A estimates the effect of positive reforms on the sample of countries that experience at least one of them, while Panel B does the same for negative reforms. Columns (1), (2) and (3) weight the count of the number of patents by the generality, originality and radicalness coefficients, respectively and then divide them by the patent count. Column (4) computes the share of patents that are considered breakthrough. Column (5) computes the number of citations per patent.

Table B12: Effect of permanent reforms on main outcomes

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Exposure x positive reforms	0.0706***	0.0132	0.0772***
	(0.0180)	(0.00917)	(0.0208)
Exposure x negative reforms	-0.131***	-0.0470***	-0.135***
	(0.0257)	(0.0142)	(0.0300)
Exposure	0.589***	0.187***	0.719***
	(0.0434)	(0.0246)	(0.0499)
Observations	69,184	69,184	69,184
R-squared	0.509	0.567	0.502

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Only permanent reforms are considered, and Brazil is excluded from the sample because it does not adopt any permanent reform over the period. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1.

Table B13: Effect of permanent reforms on migrant patents and spill-overs

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Panel A: Patents by teams with at least one GMI			
Exposure x positive reforms	0.0572***	0.0130	0.0646***
	(0.0156)	(0.00879)	(0.0177)
Exposure x negative reforms	-0.102***	-0.0475***	-0.0996***
	(0.0225)	(0.0138)	(0.0250)
Exposure	0.387***	0.169***	0.437***
	(0.0379)	(0.0237)	(0.0430)
Observations	69,184	69,184	69,184
R-squared	0.536	0.588	0.450
Panel B: Patents by teams with no GMIs			
Exposure x positive reforms	0.0766***	0.00181	0.0791***
	(0.0197)	(0.00694)	(0.0208)
Exposure x negative reforms	-0.146***	-0.0314***	-0.152***
	(0.0273)	(0.0107)	(0.0287)
Exposure	0.659***	0.128***	0.706***
	(0.0482)	(0.0208)	(0.0504)
Observations	69,184	69,184	69,184
R-squared	0.499	0.521	0.497

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Only permanent reforms are considered, and Brazil is excluded from the sample because it does not adopt any permanent reform over the period. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1.

Table B14: Effect of permanent reforms on patent quality

	(1) asinh generality per patent	(2) asinh originality per patent	(3) asinh radicalness per patent	(4) asinh share of breakthrough patents	(5) asinh citations per patents
VARIABLES	OLS	OLS	OLS	OLS	OLS
Exposure x positive reforms	0.000766	-0.000523	5.56e-05	-4.50e-05	0.000575
	(0.000867)	(0.000577)	(0.000821)	(0.000310)	(0.00492)
Exposure x negative reforms	-0.000300	-0.00314***	-0.00224	7.43e-05	-0.0193**
	(0.00153)	(0.000886)	(0.00142)	(0.000635)	(0.00974)
Exposure	-0.00179	0.00138	0.00236	-0.000462	0.0780***
	(0.00172)	(0.00106)	(0.00168)	(0.000783)	(0.0113)
Observations	51,930	59,323	59,330	59,990	59,990
R-squared	0.621	0.626	0.586	0.488	0.673

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Only permanent reforms are considered, and Brazil is excluded from the sample because it does not adopt any permanent reform over the period. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Columns (1), (2) and (3) weight the count of the number of patents by the generality, originality and radicalness coefficients, respectively and then divide them by the patent count. Column (4) computes the share of patents that are considered breakthrough. Column (5) computes the number of citations per patent.

Table B15: Main outcomes with lagged reforms

	(1)	(2)	(3)
	asinh Patents	asinh GCP	asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Exposure x positive reforms	0.0328**	0.00800	0.0359**
	(0.0158)	(0.00673)	(0.0178)
Exposure x negative reforms	-0.128***	-0.0315*	-0.130***
	(0.0298)	(0.0165)	(0.0350)
Exposure	0.657***	0.194***	0.793***
	(0.0514)	(0.0266)	(0.0590)
Observations	68,321	68,321	68,321
R-squared	0.510	0.563	0.502

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Reforms lagged by one year. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1.

Table B16: Direct and spill-over effects with lagged reforms

	(1) asinh Patents	(2) asinh GCP	(3) asinh Domestic Patents
VARIABLES	OLS	OLS	OLS
Panel A: Patents by teams with at least one GMI			
Exposure x positive reforms	0.0339**	0.00702	0.0376**
	(0.0137)	(0.00633)	(0.0151)
Exposure x negative reforms	-0.0914***	-0.0320*	-0.0915***
	(0.0272)	(0.0167)	(0.0304)
Exposure	0.421***	0.177***	0.475***
	(0.0452)	(0.0272)	(0.0507)
Observations	68,321	68,321	68,321
R-squared	0.536	0.584	0.451
Panel B: Patents by teams with no GMIs			
Exposure x positive reforms	0.0362**	0.00466	0.0382**
	(0.0168)	(0.00553)	(0.0176)
Exposure x negative reforms	-0.129***	-0.0173	-0.135***
	(0.0318)	(0.0122)	(0.0336)
Exposure	0.724***	0.123***	0.772***
	(0.0563)	(0.0207)	(0.0597)
Observations	68,321	68,321	68,321
R-squared	0.499	0.518	0.497

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Reforms lagged by one year. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1.

Table B17: Quality of patents with lagged reforms

	(1) asinh generality per patent	(2) asinh originality per patent	(3) asinh radicalness per patent	(4) asinh share of breakthrough patents	(5) asinh citations per patents
VARIABLES	OLS	OLS	OLS	OLS	OLS
Exposure x positive reforms	0.000353	-0.000360	-0.000660	-9.21e-05	0.00159
	(0.000491)	(0.000306)	(0.000473)	(0.000155)	(0.00343)
Exposure x negative reforms	3.98e-05	-0.00260**	-0.00376**	-0.000826	-0.0234**
	(0.00184)	(0.00102)	(0.00167)	(0.000515)	(0.0104)
Exposure	-0.00180	0.00128	0.00449**	1.90e-05	0.0795***
	(0.00197)	(0.00115)	(0.00184)	(0.000624)	(0.0120)
Observations	52,666	60,207	60,214	60,892	60,892
R-squared	0.619	0.622	0.583	0.487	0.671

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Reforms lagged by one year. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years, and then standardized to have mean 0 and standard deviation of 1. Columns (1), (2) and (3) weight the count of the number of patents by the generality, originality and radicalness coefficients, respectively and then divide them by the patent count. Column (4) computes the share of patents that are considered breakthrough. Column (5) computes the number of citations per patent.

Table B18: Robustness of main outcomes to excluding large countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	without CA	without CH	without DE	without UK	without IN	without IT	without JP	without KR	without TW
Panel A: Asinh. N. of patents									
Exposure x positive reforms	0.0369*	0.0349*	0.0393**	0.0210	0.0269*	0.0292*	0.0249	0.0627***	0.0356**
	(0.0207)	(0.0180)	(0.0171)	(0.0165)	(0.0154)	(0.0162)	(0.0165)	(0.0170)	(0.0172)
Exposure x negative reforms	-0.127***	-0.103***	-0.127***	-0.147***	-0.161***	-0.136***	-0.0506*	-0.136***	-0.136***
	(0.0323)	(0.0311)	(0.0354)	(0.0461)	(0.0307)	(0.0436)	(0.0290)	(0.0296)	(0.0284)
Observations	57,697	60,978	50,589	51,912	65,744	63,429	58,554	66,933	65,446
R-squared	0.522	0.505	0.536	0.516	0.516	0.513	0.516	0.520	0.511
Panel B: Asinh. N. of GCPs									
Exposure x positive reforms	0.00860	0.00698	0.00988	0.00378	0.00542	0.00777	0.00742	0.0153*	0.0103
	(0.00913)	(0.00765)	(0.00713)	(0.00713)	(0.00648)	(0.00686)	(0.00752)	(0.00851)	(0.00709)
Exposure x negative reforms	-0.0322*	-0.0294*	-0.0249	-0.0301	-0.0460***	-0.0152	-0.0171	-0.0390**	-0.0420***
	(0.0180)	(0.0173)	(0.0204)	(0.0255)	(0.0168)	(0.0244)	(0.0175)	(0.0166)	(0.0155)
Observations	57,697	60,978	50,589	51,912	65,744	63,429	58,554	66,933	65,446
R-squared	0.574	0.548	0.576	0.564	0.572	0.568	0.568	0.567	0.552
Panel C: Asinh. N. of domestic patents									
Exposure x positive reforms	0.0421*	0.0359*	0.0431**	0.0226	0.0292*	0.0316*	0.0263	0.0693***	0.0367*
	(0.0235)	(0.0201)	(0.0194)	(0.0188)	(0.0176)	(0.0183)	(0.0188)	(0.0196)	(0.0194)
Exposure x negative reforms	-0.128***	-0.100***	-0.130***	-0.154***	-0.167***	-0.141***	-0.0592*	-0.141***	-0.142***
	(0.0379)	(0.0365)	(0.0412)	(0.0543)	(0.0361)	(0.0509)	(0.0344)	(0.0348)	(0.0334)
Observations	57,697	60,978	50,589	51,912	65,744	63,429	58,554	66,933	65,446
R-squared	0.517	0.503	0.527	0.509	0.508	0.504	0.495	0.510	0.505

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1 (each regression controls for exposure alone, coefficient not reported). Each columns exclude from the sample one country with more than 5 thousands observations in the dataset (in order from left to right: Canada, china, Germany, United Kingdom, India, Italy, Japan, South Korea, Taiwan). Panel A shows the regressions on the total number of patents, and Panel B and C disentangle the outcome into GCPs and domestic patents.

C Result Extensions

C.1 Heterogeneity and extensive margin

Table C19 tests the heterogeneity of the effect across MNE size. Here the sample is split in half according to the average number of subsidiaries that an assignee has over the period. Small MNEs thus groups firms that patent in 2.6 subsidiaries in a given year on average, while large MNEs patent in 8 subsidiaries in a given year on average. Interestingly, the heterogeneity of the effect of positive and negative reforms goes in the opposite direction across this dimension. Large MNEs benefit much more from positive reforms: one additional positive reform increases patents of exposed subsidiaries by an additional 14% with respect to baseline, while only an additional 4.5% increase is observed within small MNEs. On the contrary, one additional negative reform has no significant impact on patenting of large MNEs, while most exposed small MNEs decrease patenting by 22% with respect to baseline. This result signals that large firms are able to take greater advantage of positive migration reforms, and are somewhat protected from the detrimental impact of negative reforms. Small firms are less able to profit from an increase in access to cross-border mobility, but suffer a lot from reforms restricting such access. It seems thus that migration reforms widen the inequality in patenting existing between large and small multinational companies.

Table C20 tests the heterogeneity of the effect across reform types, distinguishing between those affecting the volume of migrants and those affecting the rights of migrants. Results reveal that the effect of positive reforms is driven by legal changes affecting the volume of newcomers, while the effect of negative reforms is driven by legal changes decreasing the rights of foreign workers in the country. This finding suggests that the inventors' decision to move to a new country and to leave the said country are sensitive to different factors.

Finally, we investigate what is the impact of reforms on the extensive margin of innovation. By construction, in our data we only observe a subsidiary if it files at least one patent in a given year. Consequently, our estimates on the total number of patents have to be interpreted as the effect on the intensive margin: reforms affect the quantity of inventors migrating and the amount of patents filed among subsidiaries that do patent. In order to explore the effect on the extensive margin, we input subsidiaries in the years when they do not patent if the MNE is observed patenting in other countries in that year. For these observations, all the patent counts are set to zero. We then estimate the effect combining the intensive and the extensive margin by applying the same model to the new data, and we estimate the effect on the pure extensive margin by applying the model on dummies equal to one if at least one patent is filed in a given year.[27] Results combining both intensive and extensive margins are reported in Table C21, results on the pure extensive margins are reported in Table C22. The latter are estimated using a non-linear model (pseudo-poisson maximum likelihood), and the coefficients are reported in terms of incidence ratios. When we consider both margins, we obtain results that qualitatively confirm all the conclusions from the main analysis. Positive reforms increase the advantage of exposed subsidiaries by about 7%, while negative reforms decrease it by about 18% (vs 4.7% and 21% obtained in the main analysis). The analysis on the pure extensive margin shows that positive and negative reforms have an effect on the probability of filing GCPs. Positive reforms increase the probability of filing a GCP by about 2.3% with respect to baseline exposure, and negative reforms decrease it by about 9% with respect to baseline exposure. Negative reforms also decrease the probability of filing domestic patents (-5% wrt baseline), while positive reforms seem to operate a shift away from domestic patents towards more GCPs. The effect of positive reforms suggests that there is a fix cost associated with GCP production, such that subsidiaries already involved in these projects are not affected by additional GMIs, but subsidiaries that have not yet started to produce GCPs are sensitive to them.

C.2 Effect on productivity

In this last section, we ask whether individual productivity increases after moving to another country, and whether thus migration reforms affect the level of productivity of exposed subsidiaries. To answer the first question we construct a new dataset counting the number of patents filed

[27] Given that we use arcsinh transformations of the patent counts, the zeros are preserved in our outcome variable.

by individual inventors over time, instead of collapsing everything at the subsidiary level, and we keep in the sample every inventor that is observed changing country at least once over the period of interest (1990-2016). We then regress the number of patents that each individual files in a given year on a variable indicating whether the inventor has (just) moved from a different country, controlling for individual fixed effects, MNE x year fixed effects, country x year fixed effects and dummies for time since the first appearance of the inventor in the sample (which is a proxy for experience). The underlying assumption of this method is that the timing of migration across moving inventors is quasi-exogenous, once we control for trends explained by the MNE and the country of residence, as well as for inventor experience.

Table C23 presents the results. Column (1) considers the effect on patenting during the first year after moving, as compared to any other period. Column (2) does the same as Column (1) but restricts the movements to changes across countries within the same MNE. Column (3) captures the average change in productivity in all the years following the first movement compared to the pre-movement period. Column (4) does the same as Column (3) but restricts the movements to changes across countries within the same MNE. Results show that inventors file 3% more patents during the year after moving, and that this goes up to 14% if the movement is internal to the MNE. If we consider all years after movement as compared to the years preceding the movement there is no significant change in patenting overall, but patenting goes up by 4% on average after a movement done within the same MNE. Overall these results suggest that GMIs do become more productive after arriving in the new country.

Finally, we check whether migration policies have an impact on the productivity of subsidiaries. So far we have shown that more exposed subsidiaries increase the number of patents filed after a positive migration reform, and decrease it after a negative reform. This can either be driven by a change in the number of (patenting) inventors, or by a change in the number of patents filed by each inventor. In order to control for the size effect and isolate the effect on productivity, we divide the number of patents by the number of inventors observed patenting in the subsidiary that year. Results are reported in Table C24. Strikingly, neither the positive nor the negative reforms have an effect on the number of patents per inventor filed by the most exposed subsidiaries. This suggests that the entirety of the effect passes through an increase in the number of inventors, both domestic and GMIs, in the same proportion, which is not trivial. Interestingly, exposure to reforms is associated with lower productivity on average. This suggests that large MNEs tend to have more inventors patenting, among which some are not very productive, while in the smaller MNEs only very productive inventors patent.

Table C25 documents the effect of the reforms on overall subsidiary size, measured as the number of inventors observed patenting in a given year. What we see is that these reforms do not only impact the number of GMIs in the subsidiary, but change the number of never-moving inventors by a similar magnitude. One standard deviation higher exposure is associated with a 3% increase in GMIs and a 3% increase in never-moving inventors following a positive reform, and with a 8% decrease in GMIs and a 13% decrease in never-moving inventors following a negative reform. Our data does not allow disentangling whether the new inventors observed patenting are newly hired, or whether they were already present in the subsidiary but were not patenting. Similarly, the inventors disappearing after a negative reform might still be employed by the subsidiary but observed patenting less frequently. What we can infer from these results is that migration reforms have a very strong effect on the number of inventors observed patenting in a given country, and this effect goes beyond the impact on the number of GMIs alone. This result is very much in line with the findings of Kerr et al. (2015), who find strong complementarity in production between migrant and native workers, such that relaxation of H1-B visa restrictions lead to an expansion in native employment within affected firms. It also echoes a quote from Bill Gates during a congressional testimony stating that Microsoft hires four additional employees to support each worker hired on the H-1B visa.

The fact that individual inventors become more productive after moving to a different country, while receiving subsidiaries do not show a change in productivity, is a sign that migration reforms, by lowering mobility frictions between countries, increase the sorting of high-potential individuals towards high-potential subsidiaries.

Table C19: Heterogeneity of effect by MNE size

	(1)	(2)	(3)	(4)	(5)	(6)
	asinh Patents		asinh GCP		asinh Domestic Patents	
VARIABLES	small MNEs	large MNEs	small MNEs	large MNEs	small MNEs	large MNEs
Exposure x positive reforms	0.0195*	0.192***	0.00330	0.0811***	0.0206	0.218***
	(0.0116)	(0.0379)	(0.00280)	(0.0225)	(0.0132)	(0.0432)
Exposure x negative reforms	-0.0978***	0.102	-0.0166**	0.0837*	-0.0974***	0.142
	(0.0209)	(0.0849)	(0.00697)	(0.0487)	(0.0256)	(0.0982)
Exposure	0.428***	1.310***	0.0849***	0.526***	0.527***	1.551***
	(0.0334)	(0.135)	(0.0101)	(0.0652)	(0.0385)	(0.154)
Observations	27,985	42,953	27,985	42,953	27,985	42,953
R-squared	0.584	0.532	0.761	0.512	0.574	0.524

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years. Small MNEs are identified as the 50% of assignees with the smallest average number of subsidiaries over the period, while large MNEs are the ones with the 50% largest number of subsidiaries.

Table C20: Heterogeneity of effect by reform type

	(1)	(2)	(3)	(4)	(5)	(6)
	asinh Patents		asinh GCPs		asinh Domestic Patents	
VARIABLES	volume	rights	volume	rights	volume	rights
Exposure x positive reforms	0.0449***	0.0245	0.0124*	-0.00397	0.0475**	0.0264
	(0.0173)	(0.0361)	(0.00715)	(0.0159)	(0.0196)	(0.0409)
Exposure x negative reforms	-0.0470	-0.104**	-0.0118	-0.0169	-0.0603	-0.115**
	(0.0532)	(0.0413)	(0.0323)	(0.0222)	(0.0614)	(0.0466)
Exposure	0.576***	0.669***	0.171***	0.198***	0.712***	0.810***
	(0.0427)	(0.0429)	(0.0204)	(0.0213)	(0.0486)	(0.0482)
Observations	70,969	70,969	70,969	70,969	70,969	70,969
R-squared	0.507	0.506	0.562	0.562	0.500	0.499

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2015. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years. Columns (1), (3) and (5) look at the effect of the reforms changing the volume of immigration, while Columns (2), (4) and (6) isolate the effect of reforms touching the rights of migrants.

Table C21: Main results including extensive margin

	(1)	(2)	(3)	(4)	(5)	(6)
	asinh Patents		asinh GCP		asinh Domestic Patents	
VARIABLES	main exp	hist. exp	main exp	hist. exp	main exp	hist. exp
Exposure x positive reforms	0.0118**	0.0161***	0.00232	0.00220	0.0124**	0.0162***
	(0.00502)	(0.00494)	(0.00215)	(0.00261)	(0.00519)	(0.00511)
Exposure x negative reforms	-0.0553***	-0.0382***	-0.00658*	-0.00381	-0.0586***	-0.0397***
	(0.00729)	(0.00716)	(0.00355)	(0.00385)	(0.00743)	(0.00733)
Exposure	0.342***	0.295***	0.0762***	0.0756***	0.347***	0.299***
	(0.0147)	(0.0152)	(0.00746)	(0.00861)	(0.0152)	(0.0158)
Observations	447,156	447,156	447,156	447,156	447,156	447,156
R-squared	0.379	0.374	0.428	0.428	0.362	0.355

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2015. Patents set to zero if a subsidiary does not patent in a given year while the MNE patents in a different country (combines intensive and extensive margin effect). Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceeding 5 years. Historical exposure is computed in the same way but over the period going from 5 to 10 years prior to the observation.

Table C22: Main results on the pure extensive margin

	(1)	(2)	(3)
	P(Patent)	P(GCP)	P(Domestic Patents)
VARIABLES	main exp	cont. exp	main exp
Exposure x positive reforms	0.998	1.005*	0.990**
	(0.00215)	(0.00295)	(0.00494)
Exposure x negative reforms	0.987**	0.981**	0.977*
	(0.00563)	(0.00732)	(0.0120)
Exposure	1.211***	1.212***	1.431***
	(0.0103)	(0.0136)	(0.0276)
Observations	318,606	206,624	233,813
R-squared	0.106	0.119	0.122

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. Coefficients to be interpreted as incidence ratios. MNE x year fixed effects and country x year fixed effects included in all regressions. Pseudo-poisson maximum likelihood. Period of analysis: 1990-2015. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1.

Table C23: Results on individual inventor productivity

VARIABLES	(1)	(2)	(3)	(4)
	asinh N. of Patents			
Movement (1yr)	0.0336***			
	(0.00601)			
Movement within MNE (1yr)		0.144***		
		(0.0125)		
Movement (always)			-0.00199	
			(0.00649)	
Movement within MNE (always)				0.0403***
				(0.00767)
Observations	251,874	251,874	251,874	251,874
R-squared	0.369	0.372	0.369	0.369

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. Sample includes all inventors that are seen moving at least once over the period of interest (1990-2016). All regressions include individual FE, country x year FE, MNE x year FE, and fixed effects for years since first individual appearance (proxy for experience).

Table C24: Results on subsidiary productivity

	(1) asinh Patents per inventor	(2) asinh GCP per inventor	(3) asinh Domestic Patents per inventor
VARIABLES	OLS	OLS	OLS
Exposure x positive reforms	-0.000101	-4.84e-05	-0.000481
	(0.00151)	(0.00198)	(0.00197)
Exposure x negative reforms	-0.00303	0.000710	-0.00165
	(0.00453)	(0.00590)	(0.00453)
Exposure	-0.0571***	-0.122***	0.0644***
	(0.00563)	(0.00729)	(0.00577)
Observations	70,969	70,969	70,969
R-squared	0.491	0.521	0.575

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1. Outcomes are scaled by the number of inventors in the subsidiary

Table C25: Results on the size of subsidiary

	(1)	(2)	(3)	(4)
	asinh N. GMIs	asinh N. domestic inventors	asinh N. all inventors	Share of GMIs
VARIABLES	OLS	OLS	OLS	OLS
Exposure x positive business reform	0.0311**	0.0321**	0.0305*	4.28e-05
	(0.0122)	(0.0161)	(0.0157)	(0.00146)
Exposure x negative business reform	-0.0787***	-0.133***	-0.136***	-0.00540
	(0.0247)	(0.0333)	(0.0316)	(0.00445)
Exposure	0.340***	0.813***	0.743***	-0.0718***
	(0.0400)	(0.0542)	(0.0520)	(0.00519)
Observations	70,969	70,969	70,969	70,969
R-squared	0.488	0.474	0.487	0.446

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Standard errors clustered at the subsidiary level. MNE x year fixed effects and country x year fixed effects included in all regressions. Period of analysis: 1990-2016. Exposure to the reforms is computed as the mobility rate of inventors observed within all the other subsidiaries of the MNE over the preceding 5 years, and then standardized to have mean 0 and standard deviation of 1.

D Reform Data Construction

This appendix focuses on the collection and construction of the database of unilateral reforms to migration policy impacting high-skilled migrants. The first subsection provides the list of reforms, and the second subsection describes the collection of the larger dataset of reforms. The full dataset is available upon request.

D.1 Study Reforms

For each reform examined in this study, table D26 lists the country impacted, the year of implementation, the estimated impacts on migrants, and a brief description of the reform.

Table D26: Description of Study Reforms

Country	Year	Title	Impacts	Brief Description
Brazil	2014	Amendment of Foreign Statute	Increase Volume, Increase Rights	The amended act supports electronic visa, and gives Ministry of Foreign Affairs the power to simplify visa application process. It also implies that aliens who wish to travel to Brazil on business, as an artist or athlete does not need a visa if their country treat Brazilians the same.
Canada	2002	Immigration and Refugee Protection Act	Decrease Rights	The act was the primary federal legislation regulating immigration to Canada and created a high-level framework detailing the goals and guidelines the Canadian government with regard to immigration to Canada by foreign residents. It sets out the core principles and concepts that govern Canada's immigration and refugee protection programs, including provisions relating to refugees, sponsorships and removals, detention reviews and admissibility hearings, and the jurisdiction and powers of tribunals.

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Table D26 – continued from previous page

Country	Year	Title	Impacts	Brief Description
Chile	2005	Ratification of 'The United Nations Convention on the protection of the rights of all migratory workers and their families'	Increase Rights	Chile ratified the United Nations convention on migrant workers and developed policies to assist in their integration. Allowed immigrant children to attend school and be treated equally to native students regardless of migratory status. Healthcare access in public hospitals were granted to immigrant children and pregnant women.
China	1994	The Hundred Talents Program	Increase Volume	The initiative is one of the earliest and biggest programs in China to attract qualified scholars to conduct research in China. One-time research grant of up to $2M RMB plus housing allowance are provided to qualified personnel. Applicants need to be under 40 and work full time in China.
China	1996	Administration of Employment of Foreigners in China	Decrease Rights	The law set the guidelines for the employment of foreigners in China. This includes provisions such as - Employees without Chinese nationality must obtain an employment license; foreigners entering China for employment purposes must hold an employment visa and can only be hired for positions which cannot be filled by a Chinese national; provides exemptions for UN employees. Labour contracts with foreign workers shall not exceed 5 years. Wage, minimum wage, labour disputes and working conditions of foreign employees shall be governed by local Chinese law, etc.
China	2004	Decree No. 47, 2004: Measures for the Administration of Examination and Approval of Aliens' Permanent Residence in China	Increase volume	The act specified ""Green Card"" policy for China into 3 categories: technical, investment, and marriage. To qualify for technical immigration, aliens need to hold title of associate director/associate professor equivalent or above. Investment category required at least $500,000 investment into national recommended industries or some less developed regions. Marriage category required living in China for at least 5 years with spouse who is Chinese or has obtained permanent residency.

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Country	Year	Title	Impacts	Brief Description
China	2013	Administrative Regulations of the People's Republic of China on Entry and Exit of Foreigners	Increase volume	Visa categories were increased from 8 to 12 with adjusted scopes for F, X and Z visa. ""Illegal employment"" fine increased from 1,000 RMB to 10,000 RMB per person for the employer but not exceeding 100,000 RMB. Foreign individual would be fined for 5,000 - 20,000 RMB with potential detention of up to 15 days. Foreign students with X visa were allowed to work off-campus.
China	2008	The Thousands Talent program	Increase Volume	The program established in 2008 by the central government of China to recognize and recruit leading international experts in scientific research, innovation, and entrepreneurship.
Germany	2000	The Green Card Initiative	Increase volume	This initiative provided a non-bureaucratic means of bringing foreign experts in the information and communication technology (ICT) field to Germany. 20,000 temporary visas were created, but the program was discontinued at the end of 2004.
Germany	2005	Immigration Act of 2005 (Complete Overhaul of German Migration Policy)	Increase volume; Increase rights	This act amended the Nationality Act and introduced a new Residence Act. It simplified and reduced the number of residence titles to two: a temporary residence permit and a permanent settlement permit. For the first time, the focus was placed on long-term permanent residency for migrants, in particular for skilled workers, and on integration measures.
Germany	2012	EU Blue Card (Article 19a, German Residence Act)	Increase volume	The Blue Card introduced based on the Blue Card Directive (Directive 2009/50/EC) was designed to create a European equivalent of the popular US Green Card. In particular, this law has streamlined visa application and right of residence procedures for skilled professionals from abroad. Highly qualified members of third countries can apply for the Blue Card. Relatives of the applicant receive a work permit in parallel.
Germany	2016	Integration Act of 2016	Increase rights	The Integration Act and the Regulation on the Integration Act aim to facilitate the integration of refugees into German society.

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Table D26 – continued from previous page

Country	Year	Title	Impacts	Brief Description
India	2005	Ramanujan Fellowship	Increase Volume	Ramanujan Fellowship is meant for brilliant Indian scientists and engineers from outside India to take up scientific research positions in India, those Indian scientists/engineers who want to return to India from abroad. The fellowship is scientist-specific and very selective. The Ramanujan Fellows could work in any of the scientific institutions and universities in the country and they would be eligible for receiving regular research grants through the extramural funding schemes of various S&T agencies of the Government of India.
India	2016	India Corporate Internship	Increase Volume	The program aims at attracting overseas Indians who are currently pursing graduate studies outside India in Management/Engineering/Science & Technology to intern in India for 2 to 6 months. In summer 2016, 60 paid internship opportunities will be available at 23 well-known Indian companies.
Italy	1991	Law 39 (Martelli law)	Decrease volume	The law marked the creation of Italy's first comprehensive immigration legislation, and repealed many of Mussolini's Laws on Public Security. This law, called for increased border controls and introduced visa requirements for nationals from principal sending countries. In addition, the law set up yearly quota for legal entries and enforced expulsion of illegal immigrants.
Italy	1995	Dini Decree (amendment to Martelli law)	Increase rights	This law allowed aliens to challenge deportation before leaving Italy, requiring aliens to be employed, extending entry and stays for seasonal workers and increasing punishment for those found employing undocumented aliens or engaged in trafficking.
Italy	1998	The Single Act 286 (essentially based on Law 40 aka Turco-Napolitano law)	Decrease Volume (illegal immigration); Increase rights of legal immigrants	The law's objectives were to improve efficiency in managing the flow of immigrant labor; increase prevention and containment of illegal immigration; and expand measures for effective integration of legal foreigners.

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Table D26 – continued from previous page

Country	Year	Title	Impacts	Brief Description
Italy	2002	Law 189 (Bossi-Fini Law)	Decrease volume	Bossi-Fini Law (re)established restrictive positions on immigration by limiting legal entries and by focusing on the introduction of more effective tools to fight irregular migration. This involved significant changes like immigrant quotas, mandatory employer-immigrant contracts, stricter illegal immigration deportation practices, amnesty for illegal immigrants who have worked and lived in the country for over three months, and new provincial immigration offices to help manage immigrant workers, etc.
Japan	1992	Foreign Trainee Program	Extend Duration	For foreign trainees in Japan, if certain proficiency was achieved for language and professional skills, they were allowed for another 1 year and 3 month of work status.
Japan	1993	Technical Internship Trainee Program	Increase Volume	Foreign workers were issued training status for 1 year and 2-year work status if they pass tests at the end of the training. Trainees could only be sent from Japanese company's overseas branch.
Japan	2010	Basic Guidelines related to Policies for Foreign Residents of Japanese Descent	Increase Rights	This guideline promotes the acceptance of Japanese descendants who lacks language proficiency. The government will provide daily life support, offer jobs and respect diverse culture.
Japan	2012	Point System for Highly Skilled Foreign Professionals	Increase Volume	A point-based system was established to attract highly-skilled foreign professionals. Three types of professionals are given preferential immigration treatment: advanced academic researcher, advanced specialist/technician and advanced business managers. In each category, points were given to academic achievement, work experience, annual income and other factors. If total points reach 70, the professional will be granted a status of residence.
Japan	2014	The Act for Partial Amendment of the Immigration Control and Refugee Recognition Act	Increase Volume	Reorganizes the statuses of residence such as by establishing a status of residence for foreign nationals who possess advanced and specialized skills in order to promote the acceptance of foreign nationals who will contribute to the development of the Japanese economy amid economic globalization, and takes such measures as further facilitating the procedures for landing examinations, etc.

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Country	Year	Title	Impacts	Brief Description
Japan	2015	Revised Point System for Highly Skilled Foreign Professionals	Increase Volume	Highly skilled professional became a type of visa. The revision is meant to make foreign professionals come to Japan more easily than before.
Mexico	2010	Reform to Article 67 of General Law of Population	Increase Rights	The revision allowed migrants to report human rights violation and granted migrants rights to receive aid in event of disasters and medical treatment if their life is in danger.
Mexico	2011	Migratory Act of May 25th	Increase Rights	The Migration Law eliminated over 70 articles in the Gernal Law of Population and is now the immigration law in Mexico. The law guaranteed foreigners the right to education, health services and judicial rights. The Center for Evaluation and Control of Trust would be created to oversee the conduct of the immigration authorities. The new law has four new categories of immigration permits: Visitor, Student, Temporary Resident, and Permanent Resident. Recognition of the right's immigrants acquire, whereas foreigners with family, labor, and business ties to Mexico generate a series of rights and commitments as of the time in which they begin their day-to-day lives in Mexico, even if they have fallen into irregular migratory status for administrative reasons and provided, they have complied with applicable law.
Mexico	2012	Guidelines for Immigration Procedures and Proceedings	Decrease Rights	Mexican companies wishing to hire foreigners must obtain evidences of registration with the National Immigration Institute. Foreigners cannot change status within Mexico from a visitor visa to a work permit.
Mexico	2014	Amendment to the Immigration Law	Extend Duration, Increase Volume	A new 10-year visitor's visa was introduced for family members of a Mexican citizen or of current temporary resident and permanent resident. Income and saving requirements for temporary resident and permanent resident have been reduced.

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Country	Year	Title	Impacts	Brief Description
Philippines	1996	Migrant Workers and Overseas Filipinos Act	Increase Volume	The act established the replacement and monitoring centre jointly responsible by the department of labor and employment, overseas workers welfare administration and Philippines overseas employment administration. The centre offers returnees skill training, job opportunities, livelihood programs and etc.
Philippines	2002	Balikbayan Program (Republic Act No. 9174)	Increase Volume, Increase Rights	This program amended the Republic Act No. 6768 enacted in 1989 and granted more benefits and privileges to the balikbayan (overseas Filipino returning to the Philippines, including former Filipinos who have acquired foreign citizenship). The program granted balikbayan and their immediate families visa-free entry and stay for up to one year and tax exemption for certain purchase.
Philippines	2009	Changes to Alien Employment Permits (Department Order 97-09)	Decrease Volume	The order aims to prevent foreigners from taking jobs that could be filled up by Filipinos. DOLE may inspect the establishments employing aliens to verify the legitimacy of the employment. Aliens whose Alien Employment Permit (AEP) application was denied would not be allowed to apply for a new AEP application.
Philippines	2012	Changes to Alien Employment Permits (Department Order 120-12)	Decrease Volume	This change requires that aliens to appy for a new AEP if a new job position is assumed within their current organization or start employment in a new company. Fines were established for aliens found working in the Philippines without a valid AEP as well as for organizations employing them. Processing time of AEP application was reduced.
Philippines	2013	Extension of Visa Stay	Extend Duration	Duration of stay for aliens without visa from 151 countries (including US) was extended from 21 days for 30 days
Philippines	2015	Changes to Alien Employment Permits	Decrease Volume	This change affects aliens who wish to work in Philippines and the processes to acquire an AEP. Notable changes include a more detailed description of an AEP needs to be published in newspaper and on the DOLE for 30 days; an understudy training program for training two Filipino nationals is required for each AEP application; and the processing fees was increased.

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Country	Year	Title	Impacts	Brief Description
Portugal	2001	Law-Decree n°4/2001 of January 10: immigration law	Increase Volume	A new temporary work visa category ""stay permit"" was created for foreigners who has a work contract. The stay permit was valid for one year with the possibility of extending to a maximum of five years. Foreigners were allowed to bring their family members to the Philippines and at the end of the five-year period, foreigners can apply for a resident permit.
Portugal	2003	Law-Decree n°34/2003 of February 25: immigration law	Decrease Volume	""Stay permit"" was abolished in this version of the immigration law. A system of quotas was established based on a report on domestic skill shortage in each sector. Employers need to go through a complex procedure to employ foreigners.
Portugal	2012	Golden Visa Program	Increase Volume	This scheme grants foreign individuals a golden visa (permanent residency) if they fall into three categories: 1) invest 500,000 in real estate; 2) make capital transfer of at least 1M Euro or 3) create 10 jobs. If visa holder stayed at least 7 days in year 1 and 14 days in the remaining 4 years, he/she can apply for citizenship.
South Korea	1991	Industrial and Technical Training Program for Foreigners (ITTP)	Increase Volume	This program allowed Korean companies overseas to train foreign employees. The trainees could stay for six months with a possible extension for another six months.
South Korea	1992	ITTP	Increase Volume	The change allowed small and medium businesses without overseas presence to bring in foreign trainees as well. The duration of stay for trainees was one year.
South Korea	1993	Industrial Trainee System (ITS)	Increase Volume	This program was an extended application of ITTP. The duration of stay for trainees was extended to two years. ITS specifically targeted small and medium enterprises in the manufacturing sector that was experiencing labor shortage. The quota for industrial trainee was set at 20,000.
South Korea	1994	ITS	Increase Volume	The quota for industrial trainee was increased to 30,000

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Country	Year	Title	Impacts	Brief Description
South Korea	1995	A Measure Pertaining to the Protection and Control of Foreign Industrial and Technical Trainees	Increase Rights	Foreign trainees should be paid directly from the employers and at least the minimum wage set by the government. Trainees no longer need to surrender their passports to employers or to any other party.
South Korea	1996	ITS	Increase Volume	The quota for industrial trainee was increased to 80,000
South Korea	1998	Working After Training Program for Foreigners	Extend Duration, Increase Rights	Foreign trainees who passed certain skill tests after a two-year training period were allowed to work in Korea for another year under visa category of ""working after training (E-8)"". Workers after training were entitled to the same rights enjoyed by their Korean colleagues.
South Korea	1999	Act on Immigration and Legal Status of Overseas Koreans (The Overseas Korean Act)	Increase Volume, Increase Rights	The act allowed overseas Korean to stay and work in Korea without restrictions upon receiving an Overseas Korean (F-4) visa. The act grants the same economic and social rights held by Korean citizens to overseas Korean.
South Korea	2002	ITS	Increase Volume	The quota for industrial trainee was increased to 85,500
South Korea	2004	Employment Permit System	Increase Volume	This program allows employers to hire foreign workers in the labor shortage industries such as agriculture & stockbreeding, fishery, construction and manufacturing with less than 300 regular workers. Foreign workers are granted 'Nonprofessional Employment' (E-9) visas.
South Korea	2007	Working Visit Program	Increase Volume, Extend Duration	This program grants ethnic Koreans who hold foreign citizenship, mainly from China and Soviet Unions a working visit (H-2) visa. Visa holders can freely enter and exit Korea for five years and get employed in any company in Korea for three years.

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Country	Year	Title	Impacts	Brief Description
South Korea	2009	Contact Korea	Increase Volume; Increase Rights	Contact Korea is the government organization representing the Republic of Korea that is exclusively charged with the attraction of global talented professionals. Contact Korea includes an online platform for global talents to apply for jobs in both private and public sectors in Korea. The platform serves as a one-stop shop by providing services such as arranging online interviews, verfiying academic and professional background and dealing with visa and immigration issues.
South Korea	2010	HuNet Korea Immigration Network and Policy	Increase Volume, Increase Rights	A new online visa application system (HuNet Korea) would be implemented to include visa application and job bank for foreign professionals. Reentry procedure for foreign spouses and students was simplified. A point system would be implemented for professionals who wish to obtain resident or permanent resident status in Korea. Foreigners could also obtain residency by investing in real estate in designated local areas, for example in Jeju-si. Number of sites for naturalization interview tests were increased to make it more convenient for immigrants.
Spain	1996	Royal Decree 155/1996 - approving the implementation of regulations of Organic Law 7/1985	Increase Rights	This amendment stated that foreigners with legal status have the rights to access education and other resources. Foreigners could obtain permanent residency after 6 years or 5 years if they have permanent job permit.
Spain	2003	Organic Law 14/2003 - amendment to Organic Law 8/2000	Increase Rights, Increase Volume	This amendment increased rights to the family of legal foreigners, such as spouse could obtain his/her own residence permit when given work permit and children could obtain their own permit upon reaching adulthood. Each year government would review annual foreign worker quota.

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Country	Year	Title	Impacts	Brief Description
Spain	2009	Organic Law 2/2009 - amendment to the Organic Law 4/2000	Increase Rights	This amendment added article 2b which focused on integration of immigrants. Article 6 stated that foreign residents have rights to vote in municipal elections. Article 12 stated that foreigners have access to healthcare under the same condition as citizens. Article 38s stated that highly qualified residence would be able to obtain residence permit and EU blue card.
Taiwan	1992	Employment Service Act	Decrease Volume, Decrease Rights	The act was the first law in Taiwan to legalize hiring of certain foreign workers, strengthen the legal rights of employees, and impose sanctions on employers who hired illegal foreign laborers. Employment for foreign workers was limited to a maximum of two-year term and blue-collar foreign workers are prohibited to marry Taiwanese during employment.
Taiwan	2014	Amendments to the Regulations Governing Visiting, Residency, and Permanent Residency of Aliens	Extend Duration, Increase Rights	Adult children of foreign residents who grew up in Taiwan are able to apply for two three-year extensions of residency if they meet certain requirements. Foreign professionals who have completed their previous work assignments have up to six months of extended residency to seek new employment in Taiwan. Foreign students who graduated from Taiwan universities also have a six-month extension of residency. They qualify for employment without needing the two years of work experience as previously required.
Taiwan	2015	Global Recruiting Platform	Increase Volume	A Recruitment Policy Committee was established under the Executive Yuan that included representatives from ministries such as Economic Affairs, Education, Labour, Health and Welfare and National Immigration Agency. The platform aims to attract highly-skilled professionals from overseas to live and work in Taiwan.
UK	1996	Asylum and Immigration Act	Decrease rights	The act made it a criminal offence to employ anyone unless they had permission to live and work in the UK.

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Country	Year	Title	Impacts	Brief Description
UK	2006	Immigration, Asylum and Nationality Act	Decrease Rights; Increase Rights	A five-tier points system for awarding entry visas was created. Those refused work or study visas had their rights of appeal limited. The act brought in on-the-spot fines of £2,000, payable by employers for each illegal employee, which could include parents taking on nannies without visas.

D.2 Construction of a Database of Migration Reforms

Collecting Reforms

In constructing a sample of reforms, our starting point was the work of Branstetter et al. (2006), who indexed global intellectual property reforms previously. The countries indexed in the final data are: Brazil, Canada, Chile, China, Germany, India, Italy, Japan, Mexico, the Philippines, Portugal, South Korea, Spain, Taiwan, and the United Kingdom. Countries were selected based on the presence of (i) historical enactment of intellectual property legislation supportive of patenting, (ii) multinational activity, and (iii) significant migration flows. Ten of these countries coincide with the sample analyzed in Branstetter et al. (2006), who study the impact of systematic reforms designed to strengthen and standardize intellectual property on MNEs' resulting foreign direct investments between 1982 to 1999. Relative to that study, we expanded the sample to 5 additional countries with the aim of including countries that are the source and destination of significant migration flows. For instance, Canada and the United Kingdom are in the top four most frequent destinations of OECD migration in 2010, while India, the Philippines, and the United Kingdom, experienced the most net emigration in 2010 (Kerr et al., 2016). Additionally, several of the countries in the list are representative of high levels of net inventor immigration.

After identifying a list of countries, we turned to collecting reforms. During the period of 2017 through summer 2020, teams of RAs and the authors identified migration policy reform events impacting high-skilled human capital migration of two types into a focal country: (1) return migrants, and (2) foreign immigrants. Alongside identification, the team collected corresponding primary and secondary sources related to reforms. Collection occurred in three waves - the first in 2017, the second in Winter 2018 to Summer 2019 and the third in Summer 2020. The latter two focused on ensuring complete collection of reforms enacted in the period of 1990 to 2016. Where additional reforms were identified outside this period, they were included in the dataset. As a result, the database of reforms is primarily useful for analyses on the post-1990s era and is less reliable for reforms and initiatives prior to this point.

Starting from the second and wave, collection of reforms preceded following a standardized heuristic with emphasis on ensuring completeness in the dataset. First, a search was conducted to collect any primary or secondary news sources related to the countries under review from websites that focused on information related to migration policies and programs of countries, including websites focused on assisting immigration and websites focused on the navigating migratory legislative policies of countries. Example websites include: LegislateOnline, (http://www.legislationline.org/); The Library of Congress, (https://www.loc.gov/law/help/migration-citizenship/); and that of the think tank Migration Policy (http://www.migrationpolicy.org). Website-based searches would also turn to legal codes of countries published online by their central governments, searching explicitly for links and connections to the codified migration laws of a country (e.g., legal codes of all European Union countries are indexed on EU websites). After website searches, academic repositories were searched for articles with comprehensive explanation of migration policy reforms and initiatives. Finally, these searches were followed by a series of keyword based searches implemented in the Wikipedia online encyclopedia (https://www.wikipedia.org/) and Google's web search engine focused on identifying articles, information, and primary sources related to migration policy reforms, migration policy initiatives, and high skilled human capital immigration into and out of a country. Iteration between approaches occurred as necessary (for example, if Wikipedia revealed several individual laws to search for or programs to search for, the researcher would spend time looking for primary sources for those laws or programs in legal code and government websites). Table D27 provides a list of example searches utilized in the search process.

Categorizing Reforms

To characterize the anticipated impacts of reforms, the authors qualitatively assessed each reform and the associated primary and secondary sources. Based on this analysis, reforms were coded according to whether the anticipated effects were positive (easing movement) or negative (restricting movement) based on how the reforms impacted legal migration frameworks of countries. Specifically, reforms were classified as positive or negative according to anticipated impact along three dimensions: (i) the rights of a migrant (either foreigners or returnees), (ii) the expected volume of migrants post reform, and/or (iii) the duration of stay or required time to achieve residency status criteria associated with admission to a country. Reforms identified as generating increases (alt. decreases) along any of these dimensions were then codified as having a positive (alt. negative) effect. While rare, some reform packages simultaneously enacted provisions exhibiting both positive and negative effects. For such reform events, we treat the event as an instance of both a positive reform and a negative reform. For example, in 2006, the UK enacted administrative regulations that increased the number of visas awarded, with the impact of increasing work rights for migrants with an accepted visa, while also decreasing rights for those that encountered a visa refusal (limitation of rights to appeal). As a result, this reform is coded both as a positive and negative reform event for the United Kingdom in 2006.

Table D28 considers the subsample of all reforms affecting business migration, and presents counts summarizing reform distribution across countries by its expected impact (positive, negative, or both), by its importance in determining migration flows (major vs. minor), and by immigrant type affected (returning citizen vs. foreigner). Here we only include the reforms taking place during the years 1990 - 2016, which correspond to the period analyzed in this paper. Most countries in our sample have at least 3 reforms within the 26 years, while some countries (such as China, Japan and the South Korea) have 6 or more. A large majority of reforms - 85% - target foreigners while only 15% explicitly targeted returnee migrants. Reforms during the period leaned towards positive interventions, anticipated to increase migration, with 44 identified instances of anticipated positive effects, 2 identified instances where the outcome is ambiguous because the new legislation includes both positive and negative aspects, and only 12 with anticipated negative effects. In the complete dataset that we constructed we also collected reforms affecting student migrants or entrepreneurs. More details are available upon request.

Table D27: Example Keyword Terms Leveraged in Search

Wikipedia	Google: HS HC	Google: Catch-All
1. Migration in <Country>	1. Entrepreneurship Immigration <Country>	1. Move to <Country>
2. History of Migration in <Country>	2. Start a Business as an Immigrant <Country>	2. Immigrate to <Country>
3. Migration Policy <Country>	3. STEM Incentives <Country>	3. Immigration to <Country> <Nationality> Heritage
4. <Nationality> Citizenship	4. High Skill Migration <Country>	4. Migration Policy <Country>
5. Citizenship in <Country>	5. Refugee Immigration <Country>	5. History of Migration <Country>

Table D28: Classification of Reforms

	Positive vs Negative			Major vs Minor		Migrants vs Returnees	
Countries	positive	negative	Both	major	minor	migrants	returnees
Brazil	1	0	0	1	0	1	0
Canada	0	1	0	1	0	1	0
Chile	1	0	0	1	0	0	1
China	4	2	0	5	1	4	2
Germany	4	0	0	3	1	4	0
India	2	0	0	0	2	0	2
Italy	1	2	1	3	1	4	0
Japan	6	0	0	2	4	5	1
Mexico	3	1	0	1	3	4	0
Philippines	3	3	0	3	3	4	2
Portugal	2	1	0	2	1	3	0
South Korea	13	0	0	7	6	11	2
Spain	3	0	0	3	0	3	0
Taiwan	2	1	0	2	1	3	0
United Kingdom	0	1	1	2	0	2	0
TOTAL	45	12	2	36	23	49	10

E Estimation of Treatment Effects Give Frequently Repeated and Clustered Events

E.1 A Generalized Estimator

In a classical difference-in-differences or event-based approach, the key term of interest is an indicator variable or series of relative event-time indicators that take the value one in the periods of and subsequent to treatment. The coefficient on this key term estimates the mean difference in the response in the period(s) surrounding treatment with emphasis on those subsequent to treatment.[28] This model is inflexible in the case of repeated treatment, and standard practice is to discard observations where repeated treatment occurs. This is not feasible in all situations, however, including those where treatment events are clustered at the level of the group among observations with few group categories or where treatment events are clustered in time, as in our data.

To accommodate, we relax the requirement that the time periods examined in the difference-in-differences estimator include only the singular enactment of an event, and we treat the difference-in-differences estimator key term as a non-negative count of events enacted that can vary over time. Generalizing from the regressions in our analyses, we allow variations on models of the general form:

$$Y_{it} = f(\gamma_i + \gamma_t + \beta\ r_{it};\ \epsilon_{it})$$

where Y_{it} represents the response variable in time t for observation group i, γ indexes time and group fixed effects, and r_{it} is the count of treatment events implemented to date for group i

[28] Borusyak and Jaravel (2017) presents canonical equations that outline the generalized event-based estimator and which relate difference-in-differences specifications to event study specifications by demonstrating that the estimator is a specific case of a more general event-study specification with dynamic treatment effects. **?** examines the case of difference-in-differences estimation conditional on variation in treatment timing, shows that the treatment effect estimated is a weighted average of the treatment effect of the component difference-in-differences estimates, and proposes a test for the validity of such estimators.

in time t, and ϵ_{it} is the standard error term.[29] When only a singular event is ever enacted for any given observation, this model is equivalent to classical difference-in-differences or event-based approaches that include fixed effects that subsume the independent effects of time and treatment.

In this model, the key coefficient of interest is β, and it is interpreted as the average per-period increase in the response conditional on an additional event. For simplicity, the measurement r_{it} assigns equal weight to each consecutive reform of the same type, and as a result imposes the restriction that the average treatment effects of a given reform event type must be equivalent across reform events.

A generalized version of this measure might estimate treatment effects independently, including linearly-additive indicators for each level of consecutive treatment such that $r_{it} = \sum_{j}^{J} \sum_{t=0}^{T=t} 1(event_{it,j})$ where j indexes the various levels of treatment and where coefficients are estimated for each level of j. To economize on statistical power and maintain simplicity, we impose the restriction of equivalence in effect across treatment levels in our analyses.

Causal inference given this estimator requires additional assumptions. Literature on causal inference in the presence of repeat events (e.g., Blackwell 2013) suggests two. First, it is necessary to assume that treatment events are linearly additive in their effects and exhibit independence otherwise, with no interaction across treatment levels. Second, it also must be assumed that treatment is orthogonal to the consequences of the treated unit's prior treatment history - i.e., future treatment and impacts on the response are not significantly determined by the prior sequence of past treatment.

E.2 Simulation of Estimator Measurement Error

To evaluate whether this estimator accurately measures the corresponding causal treatment effect, we conducted computational simulations in which data based on parameters in our setting were simulated and the model fit repeatedly across several simulations. Specifically, for each

[29] In other words, $r_{it} = \sum_{t=0}^{T=t} 1(event_{it})$.

simulation s, data were generated from the following process involving 'Reform Events' across 8 years (y) affecting 15 'Countries' (c) and 10 'Firms' (f) present within those countries (where other parameters were chosen to approximate sample means in the actual data observed where possible[30]):

1. **Simulate Country Treatment Pathways:** A treatment event pathway was assigned for each simulated country with random variation in the frequency of treatment events within a given country that was defined by random variation in the probability of treatment event occurrence across countries. This occurred in two steps:

    (a) **Assign Random Country-Level Probability of Per-Year Treatment From Uniform Distribution:** $p_{cs} \sim \mathcal{U}(0, 0.4)$

    (b) **Determine Treatment Pathway From Binomial Distribution:** $T_{cys} \sim \mathcal{B}(p_{cs})$

2. **Simulate One-Way Fixed Effects:**

    (a) **Simulate Assignee Fixed Effects:** $\gamma_{fs} \sim \mathcal{N}(\mu = 10, \sigma = 3)$

    (b) **Simulate Year Fixed Effects:** $\gamma_{ys} \sim \mathcal{N}(\mu = 0, \sigma = 3)$

    (c) **Simulate Country Fixed Effects:** $\gamma_{cs} \sim \mathcal{N}(\mu = 0, \sigma = 3)$

3. **Simulate Two-Way Fixed Effects:**

    (a) **Simulate Assignee-Year Fixed Effects:** $\gamma_{fys} \sim \mathcal{N}(\mu = 0, \sigma = 3)$

    (b) **Simulate Country-Year Fixed Effects:** $\gamma_{cys} \sim \mathcal{N}(\mu = 0, \sigma = 3)$

    (c) **Simulate Subsidiary (Assignee-Country) Fixed Effects:** $\gamma_{fcs} \sim \mathcal{N}(\mu = 0, \sigma = 3)$

4. **Simulate Random Noise:** $\epsilon_{fcys} \sim \mathcal{N}(\mu = 0, \sigma = 1)$

5. **Simulate Treatment Effect w/Random Variance Across the Year-Firm-Country Level:** $D_{fcys} \sim \mathcal{N}(\mu = 3, \sigma = 1)$

[30] While fixed effects are estimates from a consistent normal distribution, the results prove robust to estimating fixed effects based on by-variable mean and standard deviation point estimates from a regression on the data that only includes fixed-effect terms.

6. **Compute Linearly-Additive Response Based on Differing Treatment Modes:**

   (a) **Treatment Affects Rate:** $y_{fcps} = \gamma_{fs} + \gamma_{cs} + \gamma_{ys} + \gamma_{fcs} + \gamma_{fys} + \gamma_{cys} + \sum_{t=0}^{T=t}(T_{cys}) \times D_{fcys} + \epsilon_{fcys}$

   (b) **Treatment Affects Level:** $y_{fcps} = \gamma_{fs} + \gamma_{cs} + \gamma_{ys} + \gamma_{fcs} + \gamma_{fys} + \gamma_{cys} + T_{cys} \times D_{fcys} + \epsilon_{fcys}$

For each of 5,000 simulations, we then fit the following regressions:

$$y_{fcps} = \gamma_{fs} + \gamma_{cs} + \gamma_{ys} + \beta r_{cys} + \epsilon_{fcys} \qquad \text{Cumulative Estimator}$$

$$y_{fcps} = \gamma_{fs} + \gamma_{cs} + \gamma_{ys} + \beta T_{cys} + \epsilon_{fcys} \qquad \text{Panel Estimator}$$

where the first equation corresponds to estimating the treatment effect on the cumulative count of events and the second equation corresponds to a panel estimator where the variable of interest takes the value one in periods where the event occurs and zero otherwise. For the resulting key coefficient of interest (β), we calculated the variance of the resulting estimates and their mean squared error defined as the mean of the square of the differences between the estimate and the actual treatment effect (MSE $= \frac{1}{5{,}000}\sum(3-\beta)^2$).

Table E29 displays the resulting estimates. Readily apparent is that the panel estimator is best suited for contexts where treatment produces a single-period shock to the response and in such cases it estimates closely the real average treatment effect. However, in the case of repeated events, the cumulative estimator most closely reflects the real average treatment effect. Additionally, when applied to the outcome derived from a model in which treatment influences the rate of the response, the cumulative estimator yields the lowest variance in the estimates as well as the lowest mean squared error across all specifications. Overall, we interpret this as strong evidence for the statistical validity of the cumulative estimator.

Table E29: Efficiency of Estimator

Model	Estimator	$\mu(\beta)$	Var.(β)	MSE	$\frac{MSE}{TreatEffect}$	$\frac{Var.(\beta)}{TreatEffect}$
Rate	Cumulative	3.006	0.349	0.349	0.116	0.116
Rate	Panel	1.475	0.794	3.120	1.040	0.265
Level	Cumulative	0.783	0.406	5.319	1.773	0.135
Level	Panel	2.984	0.688	0.688	0.229	0.229

Notes: This table provides the results from simulations designed to evaluate the efficiency of the 'cumulative events' estimator.